100-05064 Soil and Water Environmental Enhancement Program, SWEEP : current executive summaries

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SWEEP

THE SOIL AND WATER
ENVIRONMENTAL ENHANCEMENT PROGRAM

SOIL AND WATER ENVIRONMENTAL ENCHANCEMENT PROGRAM (SWEEP)

CURRENT EXECUTIVE SUMMARIES

Canada

Ontario

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SECTION 1

Technology Evaluation and Development (TED)

TED RESEARCH PLANS

The Technology Evaluation and Development (TED) Sub-program is one of five sub-programs initiated on the federal side by the joint federal-provincial Soil and Water Environmental Enhancement Program (SWEEP). SWEEP is a $30 million, 5-year agreement which began in 1986 as Canada's part of the Canada-U.S. Great Lakes Water Quality Agreement, shared equally between Agriculture Canada and the Ontario Ministry of Agriculture and Food.

The objectives of SWEEP are:

1. to reduce phosphorus loadings of the Lake Erie basin from cropland runoff; and
2. to improve the productivity of southwestern Ontario agriculture by reducing soil erosion that contributes to water pollution.

Ecological Services for Planning Ltd. (ESP) has served as manager of the TED Sub-program from its initial stages, working with the Scientific Authority from the Harrow Research Station of Agriculture Canada and the other Sub-programs of SWEEP.

In the beginning TED organized and integrated the research priorities set out in a planning workshop which gathered 70 specialists from across the province including farmers, agribusiness people, extension officers, researchers, economists and policy makers. These priorities were grouped into seven categories of farmer oriented research. These are

1. farm management systems
2. cropping strategies
3. tillage options
4. fertility management
5. pest control
6. water management
7. problem/process understanding

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

A REVIEW OF FARM-BASED SOIL CONSERVATION RESEARCH AND DEVELOPMENT

FINAL REPORT

MARCH 30, 1988

PREPARED BY: ECOLOGISTICS LIMITED, WATERLOO

UNDER THE DIRECTION OF: ECOLOGICAL SERVICES FOR PLANNING,
GUELPH - SUBPROGRAM MANAGER FOR TED

ON BEHALF OF: AGRICULTURE CANADA
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DISCLAIMER: THE VIEWS CONTAINED HEREIN DO NOT NECESSARILY REFLECT THE VIEWS OF THE GOVERNMENT OF CANADA OR THE SWEEP MANAGEMENT COMMITTEE.

A REVIEW OF FARM-BASED SOIL CONSERVATION RESEARCH AND DEVELOPMENT

EXECUTIVE SUMMARY

Accelerated efforts to conserve soil and water at the farm level are essential if programs such as the Soil and Water Environmental Enhancement Program (SWEEP) are to achieve their goals of improving water quality and agricultural productivity in Southwestern Ontario.

In light of these concerns, the Technology and Evaluation (TED) component of SWEEP initiated this study to:

- provide comprehensive information on conservation practices being tested and adopted in Ontario by farm operators experienced in conservation research and development;
- determine the reasons for choice of conservation technologies or practices within the context of particular management systems;
- to identify conservation problems that the TED program should subsequently address in its research program; and
- identify leaders in on-farm conservation who have been providing and/or are willing to provide a leadership role in technology transfer.

Personal interviews were conducted with twenty-seven farmers who are among the leaders in the range of practices and technologies that contribute to conservation farming systems. Five of the twenty-seven participants have incorporated on-farm conservation practices into commercial-sized organic farming systems.

Survey participants have demonstrated initiative in collecting information and equipment to permit on-farm practice and technology evaluation, have integrated these measures into their management systems, and have been among the first in their locale to test and adapt the particular technology. Respondents are located in 12 counties in Southwestern Ontario.

The major data collection efforts focused on completing an inventory of conservation practices and technologies employed on-farm, as well as the problems associated with their use. This inventory included information on cropping practices, tillage and planting practices, and land management practices.

Wherever possible, use of these practices was cross-tabulated with farm physical characteristics including enterprise type, main soil type, corn heat units, drainage and slope characteristics. Based on the project objectives and the small number of survey participants, the data analysis was primarily descriptive in nature.

Respondents were asked in summary to identify and rank conservation research needs that researchers should be addressing under conservation farming systems. These are listed below in order of priority:

- weed control/herbicides
- tillage system effects/packages
- specific equipment modifications; cover crops/rotations; fertility under conservation systems
- soil biosphere changes
- variety response
- allelopathic effects of winter wheat and winter rye on succeeding crops

Recommendations to the TED Program

As a result of these and other survey findings, recommendations have been made to the TED Program in four areas of conservation research: agronomy; tillage/planting equipment and systems; technology transfer within the farm community; and, institutional and agency response.

A. Agronomy

i) Herbicides
- Application rates, timing of application and combinations of herbicides currently registered for use under conventional tillages should be thoroughly tested under a variety of soil texture and residue types within conservation tillage systems.

ii) Cover crops and rotations
- Research should be undertaken to determine:
  - the cause of, and means to alleviate allelopathic effects of heat and rye stubble on succeeding crops
  - the extent of nitrogen benefits from legume crops under fall vs. spring killing and tilling
  - cover crops effective in suppressing weeds under any tillage system
  - effective means of controlling quackgrass in corn without using residual herbicides

iii) Seed varieties/Fertilizer forms and placement
- Evaluations of currently available seed varieties, and fertilizer forms and placement should be undertaken under all tillage/planting systems which alter residue management relative to conventional systems.

B. Tillage/Planting Equipment and Systems

i) TED, in cooperation with experienced and practicing farmers, should document the development of system packages which incorporate state-of-the-art knowledge regarding conservation tillage systems. Trouble-shooting tips and contact people to assist in problem resolution should be included.

C. Technology Transfer

i) Among Conservation Leaders
- Where possible, TED should provide support for maintaining conservation leaders on the leading edge of farm-based conservation practice and technology development. This could take the form of providing a central location for state-of-the-art conservation information, supporting publication of a newsletter, or providing funding for workshops to review advances in conservation research and development.

ii) Within the Farm Community
- TED should promote continued and expanded Soil and Crop Improvement Association conservation-oriented activities such as those currently being undertaken through the Joint Agricultural Soil and Water Conservation Program. Such endeavours facilitate information exchange between farmers with varying degrees of experience in conservation farming.

iii) Exchange Between Organic and Conservation Farmers
- TED should promote information and technology exchange between onservation and organic growers in areas of mutual interest.
- TED should also consider holding consultation with organic growers to assess the most promising conservation practices and their applicability to conventional conservation systems.

D. Institutional/Organizational Responses

i) Registration of Herbicides
- TED should encourage Agriculture Canada to take the appropriate steps to speed, where possible, the registration process of environmentally safe and effective herbicides and tank mixes for pre-plant burndown of weeds and cover crops.

ii) Communicating TED Research Mandate to Conservation Leaders
- TED should clearly articulate its mandate to conservation leaders in a way that demonstrates the necessity in the long-term for 'statistically defensible' results.

iii) Context for Research
- TED should explore ways to expand the network of farm cooperators who are currently conducting on-farm research.
- Furthermore, TED should consider areas of research that could be termed "farm-based evaluations" in which farmers manage the evaluation process. Compiling tillage system packages or evaluating particular equipment prototypes are possible ways farmers could contribute to this evaluation process.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

ASSESSMENT OF SOIL COMPACTION AND STRUCTURAL DEGRADATION IN THE LOWLAND CLAY SOILS

FINAL REPORT

MAY, 1988

PREPARED BY: CAN-AG ENTERPRISES, GUELPH, ONTARIO

UNDER THE DIRECTION OF: ECOLOGICAL SERVICES FOR PLANNING,
GUELPH - SUBPROGRAM MANAGER FOR TED

ON BEHALF OF: AGRICULTURE CANADA
RESEARCH STATION,
HARROW, ONTARIO NOR 1GO

DISCLAIMER: THE VIEWS CONTAINED HEREIN DO NOT NECESSARILY REFLECT THE VIEWS OF THE GOVERNMENT OF CANADA OR THE SWEEP MANAGEMENT COMMITTEE.

EXECUTIVE SUMMARY

Highlights of the major subject areas on subsoil compaction and structural degradation covered by this study in five counties in Southwestern Ontario are included in this summary. Recommendations and conclusions are based on results of field investigations, farmer interviews, laboratory analysis and review of scientific literature dealing with the problem of subsoil compaction on agricultural lands.

The Problem

This study focuses on the soil layer below the plow layer (i.e. about 15 to 30 cm below ground surface). Soil compaction may include one or more of these conditions: degraded soil structure; reduced size, abundance and continuity of vertical cracks and pores; smearing; increased soil bulk density; layering; and, altered rooting pattern and depth. These conditions tend to reduce the soils' ability to produce abundant crops due to deterioration of root zone quality. Soil permeability is also reduced and this results in increased runoff and erosion.

The main goal of this study was to determine the magnitude and extent of subsoil compaction and to evaluate its agricultural and environmental impacts.

Agro-environmental Setting

Southwestern Ontario is intensively farmed: the main crops grown being corn, cereals, beans (soy and white), hay and fresh vegetables.

Soils studied include predominantly clays, clay loams, silty clay loams, and silty clays on level to very gently undulating topography. Parent materials are either till, lacustrine deposits or lacustrine veneers over till. Soil drainage commonly ranges from imperfectly to poorly drained and many sites examined are tile drained.

To manage these fine textured, level soils for some of the crops grown, especially corn, many farmers try to get on their fields as early as possible in spring. The combination of tillage under fairly wet conditions using large, powerful and heavy tractors can contribute to soil compaction. Alternative cropping practices many be better for the soil but they may be less profitable, at least in the short term. Research has demonstrated that compaction does not occur when soils are worked under proper moisture conditions.

Measurements of Compaction

Several methods are used to measure soil compaction and five of the more popular ways were used in this study: visual observations of a combination of factors; bulk density determinations, hand and cone penetrometer measurements and detailed descriptions of soil peds and pores (tubular and planar).

Statistical Analysis

The degree of compaction was assessed using various statistical procedures to establish relationships among measured and observed soil properties. A visual compaction rating proved to be a good measurement, although it is subjective. Resultant ratings into slight, moderate and severe compaction categories using this approach gave essentially the same results as using a combination of all measurement techniques.

A point transect method was used to locate study sites throughout the area in an attempt to obtain unbiased estimates on the extent of compaction.

Soil compaction measurements were statistically compared to various agronomic management practices to identify significant linkages. Items examined included different measurements of soil compaction, tractor size, crops, rotations, tillage practices, fertilization methods, weed control practices, harvesting, number of passes, and others.

Results

Soil compaction is a serious problem in Southwestern Ontario. Statistical analysis indicates that about 50 to 70 percent of the clay to clay loam soils in the Counties of Middlesex, Lambton, Essex, Kent and Elgin are affected. Of this total, about 25 percent are severely compacted and 75 percent are moderately affected. Impacts of compaction are estimated to be the following:

	Moderately Compacted	Severely Compacted
Crop Yield Reduction	12%	25%
Increased Soil Erosion	17%	39%
Increased Phosphorus Loadings to Great Lakes (kg/yr)	35,000	39,400

In terms of dollars, decreased yields represent by far the greatest shortfall on returns. Increased soil erosion is very important in that it is a hidden cost to the farmers and contributes sediments and nutrients to streams. However, from the farmers' viewpoint these costs are minor compared to yield losses. The phosphorus loadings to the Great Lakes attributable to compaction are in the order of 10 to 15 percent of the total phosphorus loadings from agricultural lands. It is noteworthy that soil husbandry practices undertaken to minimize or ameliorate the compaction problem to increase yields will simultaneously reduce the harmful environmental impacts.

Important factors considered to be contributing to compaction include:

Factor	
-Size of tractor	Increasing compaction related to bigger tractors
-Number of passes	More passes, especially when soils are wet
-Crops grown	Forages < small grains < row crops < silage corn and tomatoes

Natural amelioration of subsoil compaction through freeze-thaw and wetting-drying cycles is a slow process and is not practical in an agricultural time frame. Subsoiling using heavy duty chisel plows and subsoilers may be helpful but results to date are mixed. Further work is needed to determine the most effective methods of mechanically ameliorating compaction.

Management practices that farmers can implement to minimize or prevent compaction include:

-reduce vehicle weights below critical limits (dependent on soil conditions and tires)
-avoid traffic on wet or very moist fields
-limit the number of passes and control traffic

-utilize cropping systems which facilitate the above
-reduce tire pressures, unknown how beneficial duals are with respect to subsoil compaction
-using practices which maintain soil flora and fauna

Recommendations

Several questions arise from this study that should be answered in order to help farmers deal with the compaction problems. These include:

-refinement of visual methods for quickly assessing seriousness of compaction and compaction hazard considering soil characteristics and moisture conditions.

-better understanding of the role of rotations vs. monoculture, including crop yield and compaction relationships.

-research into the use of different tires (radials, duals, floatation tires, loading vs. slippage)

-development and application of computer models to make better estimates of the effects of compaction on erosion and phosphorus removal

-development of an integrated, holistic model for soil compaction which would allow a farmer to chose the best combination of cropping practices, machinery and tires for his soil conditions and farming operation.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

CHOICE AND MANAGEMENT OF COVER CROP SPECIES AND VARIETIES FOR USE IN ROW CROP DOMINANT ROTATIONS

FINAL REPORT

May, 1990

Prepared by:	RESOURCE EFFICIENT AGRICULTURAL PRODUCTION (REAP) - CANADA, Ste. Anne-de-Bellevue, Quebec
Under the Direction of:	ECOLOGICAL SERVICES FOR PLANNING LIMITED, Guelph, Ontario - Subprogram Manager For TED
On Behalf of:	AGRICULTURE CANADA RESEARCH STATION, HARROW, ONTARIO N0R 1G0
Disclaimer:	The views contained herein do not necessarily reflect the views of the Government of Canada or the SWEEP Management Committee.

Executive Summary

The management of cover crops in four major field crops (corn, soybeans, winter wheat and spring cereals) was evaluated over a two year period on farms in South Western Ontario. The research was established within the framework of a corn soybean cereal rotation sequence. The presumption is that from an economic and environmental standpoint this sequence will develop in the 1990's to become the dominant farming sequence used in South Western Ontario on farms that do not grow forages. The experiments are classified in three stages around this rotation with overlap between years.

Stage 1	Stage 2	Stage 3
Corn	**Soybean**	**Cereal**

Individual findings are summarized below.

1 Comparison of Ryegrass Cultivars for Interseeding in Corn

There was no suppression of corn yield when ryegrass interseedings were performed on the final cultivation approximately 35 days after corn planting. Ryegrass cultivars demonstrated considerable differences in biomass production. Only one perennial ryegrass cultivar (Ellett) produced as much fall biomass as the four annual cultivars. In general, biomass production was low. To increase biomass production, the interseedings should likely be overwintered and restricted to sites with corn yields below 10 t/ha. Aside from the soil conservation value of the interseedings, a major benefit was weed suppression. Biomass of the weeds present on the sites (quack grass and a variety of annual grass and broadleaf weeds) was on average reduced by 50% by the productive ryegrass interseedings.

2 a) Rye Tillage Management Systems for Soybeans

Very high ground cover was obtained when winter rye was managed as a no-till mulch versus systems where the rye was disced or plowed. Achieving adequate soybean stands proved difficult in the treatments where tillage occurred and soybean yields were low. In tilled plots, the most promising treatment appeared to be that in which rye was harvested as a forage and the stubble subsequently plowed before soybean planting.

2 b) Soybean No-till Systems with Rye.

In the drought year of 1988, better soybean stands and yields were obtained where soybeans were no-tilled into standing rye, than where rye was first mulched and soybeans subsequently no-tilled. A high soybean yield (3.0 t/ha dry matter) was obtained when planting before mowing was performed at rye heading. Delaying no-till seeding until rye anthesis (1 week later) reduced soybean yields to 1.7 t/ha as germination was delayed until the drought ended. Rye harvested as a silage at heading yielded 3.45 t/ha dry matter and enabled timely no-till soybean planting. When the rye was left on the surface as a mulch, no annual weeds were observed in any of the treatments, and 100% ground cover was obtained.

2 c) Evaluation of Rye Varieties for No-till/Mow-kill Soybean Production

Rye varieties demonstrated considerable differences in early spring ground cover, biomass production at heading, and heading date. After no-till planting and mowing, Kustro grain rye, had 50% less regrowth than the forage rye Wheeler. Soybean yields were 40% lower on average on the rye cover cropped plots than the no-tilled soybeans without a rye cover crop. Soybeans on the rye mow-kill plots were shorter and chlorotic. The mow-kill system provided good weed control without herbicides and eliminated the need for a contact and broadleaf herbicide which was required in the no-till treatment without a cover crop.

2 d) High Moisture Winter Barley Soybean Relay Cropping

Dry weather, poor winter barley survival, and poor penetration by the no-till drill combined to cause poor success with this system. No soybeans suitable for combining were obtained from any of the relay cropped soybeans. The high moisture relay cropped winter barley (on average harvested at 43% moisture) provided for a winter barley harvest two weeks earlier than when left for grain. However, high moisture relay cropped winter barley, on average resulted in 35% lower winter barley yields than monoculture winter barley. The barley was likely harvested earlier than physiological maturity. When the relay cropped barley was combined as dry grain in 1989, a 50% reduction in barley yield resulted from barley lodging, and soybeans growing into the barley canopy.

3 a) No-till Winter Wheat and Red Clover Plowdown Following Soybeans.

No-till wheat systems of aerial seeding at leaf yellowing in soybeans and zero-till drilling after soybean harvest provided good establishment and wheat yields equivalent to conventionally tilled and planted winter wheat. Ground cover was substantially increased by both no till planting methods. Aerial seeding provided slightly higher ground cover than no-till drilling at both sites. On average, aerial seeding provided 90% ground cover when measured in late October and late April. Following winter wheat harvest, neither weed growth or fall biomass production of red clover plowdown was affected by the method of establishment of the winter wheat.

3 b) Interseeding and Catch Crop Systems for Winter Wheat

In 1988, hairy vetch drill seeded in winter wheat in mid May produced significantly higher quantities of above ground biomass (3367 and 2554 kg/ha on the silt loam and sandy loam sites respectively in 1988) than other interseeded species (red clover, crimson clover, and nitro alfalfa). Clover established poorly on the sandy loam site in the drought year. On the silt loam site in 1988, establishment and biomass production were highest the earlier the red clover was seeded (March 15) while in 1989 the best establishment and biomass production was achieved at the latest seeding date (May 15). A fall catch crop of oilseed radish produced very high fall biomass in 1988 on the sandy loam site (3654 kg/ha) while the growth on the silt loam site (950 kg/ha averaged over two years) was poorer. The difference was likely related to low residual soil N on the silt loam site. Interseeded hairy vetch and oilseed radish seeded after wheat harvest were competitive with fall weed growth when a diverse weed flora was present. However, at the sandy loam site in 1989, all the cover crops were out competed by a heavy quack grass infestation.

3 c) Interseeding and Catch Crop Systems for Spring Cereals

Red clover, hairy vetch and crimson clover interseedings were extensively killed in the drought on the sandy loam. Alfalfa was the interseeded cover crop producing the highest biomass. The few crimson clover plants that did survive the drought grew very well on the sandy loam soil. Blind harrowing, just prior to grain emergence, increased the weed infestation. On the clay loam site, hairy vetch seeded at blind harrowing produced very high fall biomass (3446 kg/ha) but climbed extensively in the grain at harvest.. The highest biomass producing system at both sites was the treatment in which liquid manure was applied; it stimulated growth of both oilseed radish and regrowth of the cereal. However, the oilseed radish seems to be more suited for use after winter cereals because the spring cereals regrew aggressively and provided approximately 50% of the fall biomass.

3 d) Interseeded Cover Crops and Mechanical Weeding Systems in Spring Cereals in 1989.

A more extensive study was performed to further evaluate mechanical weeding systems and their compatibility with establishment of red clover and the annual cover crops (crimson clover and hairy vetch). Hairy vetch introduced at finger weeding (approximately 30 days after main crop seeding) and drill seeding (approximately 45 days after main crop seeding) produced the highest fall biomass amongst cover crop treatments. Climbing of the hairy vetch in the grain at harvest was greatly reduced compared to 1988, with no appreciable climbing occurring in the drilled treatment. On the clay loam site, the mechanical weeding devices (finger weeding, harrowing, and rotary hoeing) doubled fall biomass production from the clover cover crops compared to surface broadcasting without shallow incorporation. Post emergent harrowing appeared to be too aggressive on the grain crop and caused significant plant loss, particularly in the wheel traffic areas. Both finger weeding and rotary hoeing significantly reduced weed biomass at grain harvest at the silt loam site. Overall, the rotary hoe appears to hold the most promise of the two devices as the finger weeder plugs where corn stalks are present.

4 a) Effect of 1988 Interseeded Cover Crop and Catch Crop Systems in Winter Wheat on Nutrient Cycling and Corn Yield in 1989.

The most promising cover crop treatments at the silt loam site and sandy loam site were evaluated for their effect on nutrient cycling and corn yield. Whether measured by differences in corn grain yield or leaf ear N content at silking, estimates of nitrogen release from cover crops were very similar. Unfertilized hairy vetch provided corn yields equivalent to corn fertilized with approximately 100 kg / ha fertilizer N at both sites. The other cover crop species tested: red clover (on the silt loam site), and crimson clover and oilseed radish (on the sandy loam site), provided unfertilized corn yields equivalent to corn fertilized with approximately 75 kg N/ha. Sampling to determine differences in phosphorus nutrition among treatments taken at the five leaf stage indicated a high correlation between N and P content. Legumes cover crops showed positive effects on N and P content. Oilseed radish significantly reduced uptake of phosphorus and nitrogen at the five leaf stage.

4 b) Effect of 1988 Interseeded Cover Crop and Catch Crop Systems in Winter Wheat and August Manure Applications on Nutrient Cycling and Corn Yield in 1989.

Red clover generally provided higher leaf ear N contents and corn yields than other cover crop species tested (crimson clover, hairy vetch, nitro alfalfa). Unfertilized red clover provided corn yields equivalent to corn fertilized with approximately 50 kg N/ha. Cultivation after the cereal grain harvest in 1988 reduced 1989 corn leaf ear N and corn yields by approximately 20% compared to the uncultivated control plot. Application of manure in August 1988 had little impact on leaf ear N or corn grain yield in 1989. Significant loss of nitrogen may have been experienced at this site as a result of wet field conditions and early release of nitrate from the annual cover crops. Comparisons indicated that although the five legume cover crop treatments had lower soil P than manure treatments, P content of the corn at the five leaf stage was increased significantly. Nitrogen levels in the corn at the five leaf stage were also increased significantly by the legume cover crops.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

THE EFFECT OF MOLDBOARD SHAPE ON THE RESIDUE MANAGEMENT POTENTIAL OF THE MOLDBOARD PLOW

FINAL REPORT

July, 1990

Prepared by:	CONSERVATION MANAGEMENT SYSTEMS A Division of ECOLOGISTICS LIMITED, Lucan, Ontario
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On Behalf of:	AGRICULTURE CANADA RESEARCH STATION, HARROW, ONTARIO N0R 1G0
Disclaimer:	The views contained herein do not necessarily reflect the views of the Government of Canada or the SWEEP Management Committee.

Executive Summary

The erosion of agricultural land and the associated pollution of Lake Erie with sediment and phosphorus have been identified as major agronomic and environmental problems in Ontario (1,2). Of the several methods available to control soil erosion and phosphorus movement conservation tillage systems are rated among the best (4). A need exists for conservation tillage system that will maintain crop yield and provide adequate residue cover.

Fall weather conditions in Ontario often prolong harvest and fall primary tillage is done is excessively wet soil. Under these conditions the moldboard plough has been and will likely continue to be the implement of choice for many farmers. The main problem in using the moldboard plough is that the implement tends to bury almost all residue from the previous crop. As a result the potential for controlling soil erosion is considered poor. Little work has been done to improve this performance.

In order to understand and determine the potential for using the moldboard plough as a conservation tillage tool, two approaches were examined. The first included documenting the relative amounts of residue cover obtained after ploughing cereal and grain corn stubble with three commercially available shapes and makes of moldboards. The second approach, incorporated into the same research trial, involved studying the residue management capabilities of different configurations of the modified moldboard plough as first used by Vyn, Daynard and Ketcheson (8,9).

The modified moldboard trial was located on three different sites in Essex county. Site 1 was located on cereal stubble on a clay soil located near Comber, Ontario. Sites 2 and 3 were located on grain corn stubble on clay loam soils near Harrow, Ontario.

The trial was set up as a split-plot design consisting of four replications. The main plot treatments included three of the most popular commercially available shapes and makes of moldboards and moldboard ploughs. The three plough makes selected were Overum, White and John Deere. The subplot treatments consisted of three modifications (cuts) to the moldboard shape and one control (full size moldboard).

Soil surface residue cover data were collected at four different times within the project time frame. They included: before ploughing (fall '88); after ploughing (fall '88); after spring run-off (early spring '89); and after planting (spring and summer '89). Prior to treatment implementation it was found that, in general, Site 2 had 13 percent less residue cover than Sites 1 and 3. All sites had an average residue cover above 80 percent.

In general, the third cut on all three types of ploughs left the greatest amount of residue in fall after the ploughing treatments were implemented in spring, after run-off, at all sites.

As a result of abnormal weather in Essex county in the spring and summer of 1989 the seedbed was prepared twice at Sites 2 and 3. This probably caused some residue to be destroyed, buried or moved out of the plot area, thus influencing the amount of residue left after planting. The amount of soil surface residue left after planting for all sites was well below the Ontario benchmark of 20 percent cover needed for erosion control.

When after planting soil residue cover was measured it was found that on Site 1 the third cut on the moldboards for all three plough makes and the second cut on the White plough left significantly more residue cover. At Site 2 the White first cut treatment and at Site 3 the John Deere second cut treatment left significantly more residue than other treatments.

Moldboard draft was measured using a unit designed and built by the Ontario Centre for Farm Machinery and Food Processing Technology (OCFMFPT) that was mounted between the tractor hitch and the plough. Two load cells measured the pull in the left and right lower links of the tractors 3-point hitch. It should be noted that for each plough make one side of the linkage to the tractor (right hand link for the Overum, left hand link for the White and John Deere) pulled with greater pounds force than the other side of the linkage regardless of the moldboard shape. The magnitude of the difference in pull varied somewhat between moldboard cuts and was not always greater as more cuts were made relative to the pull recorded for full size moldboards.

Volumetric soil moisture content was measured using a device called IRAMS and a Campbell Pacific Nuclea Portaprobe. The moisture content was measured on the day of ploughing (all sites) and the day of planting (Sites 2 and 3). The volumetric soil moisture content on the day of ploughing and the day of planting were quite similar among treatment plots within each site. As a result the potential effect of soil moisture content on other parameters measured was considered equal across all treatments.

The soil surface conditions after ploughing were visually assessed after all ploughing treatments were implemented. The conditions tended to be relatively even and smooth for all moldboard treatments except the third cut treatment across all three sites.

Soybean plant emergence and vegetative growth stage data were collected at the cereal stubble site (Site 1) but heavy rains and crusting experienced in the Essex county may have influenced these site specific results.

After one year of study the following conclusions were made:

1. Soil residue cover left after ploughing and spring run-off tended to increase as a greater portion of the moldboards was removed.
2. Soil surface smoothness after ploughing tended to decline as a greater portion of the moldboards was removed.
3. At a furrow width of 16 inches, maintenance of a 6 inch ploughing depth became more difficult as a greater portion of the moldboards was removed.
4. Although the magnitude of the increase in residue cover left on the soil surface after ploughing with modified moldboards was substantial at two of the three sites, the actual amount of residue cover remaining after ploughing and spring run-off tended to be slightly less or within 20 to 30 percent.
5. For the Overum and John Deere ploughs, the specific draft tended to decline as a greater portion of the moldboards was removed. Specific draft of the White plough tended to increase at the two of three sites.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

THE EFFECT OF TERRACES ON PHOSPHORUS MOVEMENT

FINAL REPORT

July, 1990

Prepared by:	ECOLOGISTICS LIMITED Waterloo, Ontario
Under the Direction of:	ECOLOGICAL SERVICES FOR PLANNING LIMITED, Guelph, Ontario - Subprogram Manager For TED
On Behalf of:	AGRICULTURE CANADA RESEARCH STATION, HARROW, ONTARIO N0R 1G0
Disclaimer:	The views contained herein do not necessarily reflect the views of the Government of Canada or the SWEEP Management Committee.

THE EFFECT OF TERRACES ON PHOSPHORUS MOVEMENT

EXECUTIVE SUMMARY

A variety of structural erosion control techniques have been tested and implemented as a means of reducing the rate of soil loss from agricultural land. Terracing, in particular channel terracing, is one structural approach which is gaining popularity for use on Ontario farms. Unfortunately, data which quantifies the effect terraces have on the quality of runoff water is limited. A monitoring technique is needed to gather data required to assess terrace efficiency in reducing phosphorus and sediment loads from terrace-protected lands. In order to address this need, a number of tasks were identified and undertaken in this study. Tasks included the development, selection and laboratory testing of a terrace monitoring apparatus, the field installation of the apparatus, field data collection and analysis, and computer simulation of the monitored events.

The monitoring apparatus developed and installed can best be described when viewed as being two sub-systems which are integrated through data acquisition hardware and software. The purpose of the inflow monitoring sub-system is to enable determination of the quantity and quality of runoff water entering a terrace's ponding area. The outflow monitoring system measures the level of flow exiting the terrace through the tile system and facilitates collection of water quality samples from that same water.

Laboratory tests were conducted on the monitoring apparatus prior to its field installation. Field installation was undertaken on a terraced site receiving runoff water from a 2.4 hectares watershed planted to a white bean crop. Once installed, the system was checked weekly to download the continuously-collected data and ensure that power levels for the various electronic components were maintained.

The field site was monitored for a period of eight months (April through November inclusive). This period corresponded to a relatively dry period for the study site. As a consequence, only one (1) storm event occurred which was sufficient to generate runoff and ponding at the monitored terrace. While laboratory testing instilled confidence in the operation of the monitoring apparatus, the single storm event which was available to field test the equipment identified other technical problems which went undetected during the lab testing phase. Problems encountered in the initial field test, for the most part, could be overcome relatively easily and quickly. The most difficult problem to overcome centred around the sub-zero temperatures experienced just prior to the event which is believed to have damaged the submerged pressure transducer used to measure pond water level.

As a consequence of the problems encountered in the initial field testing opportunity, the data collected for the event was incomplete. A thorough analysis, along with some extrapolation of the data which were available however did enable formation of a complete picture of the event. For this rainstorm, which closely matched the characteristics of a 1 hour, 2 year return period storm, the terrace was found to be between 10 percent and 15 percent efficient in trapping sediment and associated phosphorus. This is much lower than the 97 percent sediment trapping efficiency measured in a previous U.S. study (Mielke, 1985). The reason for this difference is apparent when the inflow and outflow hydrographs for the event in this study are reviewed. Peak discharge rates were nearly identical for both the inflow and the outflow hydrograph suggesting little opportunity for the inflow water to pond and deposit sediment. Thus the terrace system in this situation was acting in a fashion more characteristic of a tile/catchbasin system. Further monitoring and analysis of a range of storm events is necessary before any general conclusions can be made concerning terrace trapping efficiency. Recommendations include techniques for avoiding the technical problems detected during the field test.

Three different soil erosion computer modules, AGNPS, CREAMS and SEDCAD', all of which include algorithms for assessing the effectiveness of terracing were applied to the study site using the monitored storm event as the input rainfall. AGNPS and CREAMS give results similar to the field observed data. SEDCAD' algorithms overestimated terrace efficiency. For all models to generate reasonable results, calibration of the hydrology and sedimentology components was necessary. Results of both the monitoring and modelling aspects of the study have re-emphasized the need for designers of such systems to optimize the ponding time to facilitate the settling of sediment and yet avoid damage to the crop within the zone of temporary ponding.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

EFFECTS OF SUBSOILING ON CORN YIELDS AND SOIL CONDITIONS IN SOUTHWESTERN ONTARIO

(1988 Growing Season)

FINAL REPORT

September, 1990

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Under the Direction of:	ECOLOGICAL SERVICES FOR PLANNING LIMITED, Guelph, Ontario - Subprogram Manager For TED
On Behalf of:	AGRICULTURE CANADA RESEARCH STATION, HARROW, ONTARIO N0R 1G0
Disclaimer:	The views contained herein do not necessarily reflect the views of the Government of Canada or the SWEEP Management Committee.

EXECUTIVE SUMMARY

Twelve farmers from Kent County in southwestern Ontario co-operated in this study to observe the effect of subsoiling on corn yields and soil conditions.

Problem

This study focused on the subsoiler performance in the soil layer below the plow depth (ie. about 15 to 30 cm below ground surface). This region within the soil profile is where compaction can occur. Soil compaction may include one or more of these conditions: degraded soil structure; reduced size, abundance and continuity of vertical cracks and pores; smearing; increased soil bulk density; layering; and, altered rooting pattern and depth. These conditions tend to reduce the soils' ability to produce abundant crops due to deterioration of root zone quality. Soil permeability is also reduced and this results in increased runoff and erosion.

A previous Can-Ag compaction study indicated that about 50 to 70 percent of the clay to clay loam soils in several southwestern Ontario counties are affected. Of this total, about 25% are severely compacted and 75% are moderately affected resulting in crop yield reduction, increased soil erosion, and increased phosphorus loadings to the Great Lakes.

Purpose

The purpose of the study was to evaluate the B.C. Sub-mulcher, a narrow shank subsoiler, pulled through corn rows at depths of 18 and 31 cm in June of 1988. Not only did we look at the soil and plant response to the subsoiling, but also to determine what other management practices may affect soil compaction and yields.

Measurements of Compaction

Several methods are used to measure soil compaction and five of the more popular ways were used in this study: visual observations of a combination of factors; bulk density determinations, hand and cone penetrometer measurements and detailed descriptions of soil peds and pores (tubular and planar).

Statistical Analysis

The degree of compaction was assessed using two kinds of statistical analyses; a Pearson Correlation matrix and an analysis of variance. The ANOVA established differences among subsoiling treatments with respect to yields and measured soil properties. The Pearson Correlation matrix was made to examine correlations among various parameters measured and described.

Results

The 1988 growing season lacked significant rainfall which contributed to below average yields. These abnormally dry conditions were excellent for the subsoiling operation but caused some yield loss in the subsoiling test strips.

Results indicate that shallow (18 cm) subsoiling was detrimental to yields: deeper subsoiling did not, on the average, have any effect. However, in the sites determined to be severely compacted, yields responded very favourably to deep subsoiling.

Subsoiling improved soil conditions, though these improvements were confined to a 20 cm width centered over the shank path.

An interesting management correlation showed an increase in yields with an increase in field operations, even though this has the potential to increase compaction. The dry season probably was the major factor for this observation. Since there was not any extensive periods of wet soil conditions during critical times for field operations, compaction associated with these operations did not occur. This points out the importance of proper timing of field operations in conjunction with soil conditions.

Recommendations

A few recommendations arising from this study concern the use of a post emergence subsoiler, especially in a dry year.

These include:

- pulling a packer behind the subsoiler to close the openings left by the subsoiler shanks to reduce moisture loss through evaporation;
- the use of a subsoiler after wheat harvest where the soil is dry and there is no resulting moisture stress on a crop; and
- further research on subsoiling timing and effects of implement design.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

EFFECT OF AMMONIA ON SOIL PROPERTIES AND RELEVANCE TO SOIL AND WATER QUALITY

FINAL REPORT

October, 1990

Prepared by:	ECOLOGISTICS LIMITED, Waterloo, Ontario
Under the Direction of:	ECOLOGICAL SERVICES FOR PLANNING LIMITED, Guelph, Ontario - Subprogram Manager For TED
On Behalf of:	AGRICULTURE CANADA RESEARCH STATION, HARROW, ONTARIO N0R 1G0
Disclaimer:	The views contained herein do not necessarily reflect the views of the Government of Canada or the SWEEP Management Committee.

SUMMARY

Injection of anhydrous ammonia (AA) into soil causes high pH and high ammonia concentrations in an ammonia retention zone around the point of injection. These conditions might decrease soil productivity and increase erosion because they can cause hydrolysis of organic C, loss of soil structural stability, and inhibition of microbial activity. Two laboratory experiments (Experiment 1 and Experiment 2) were conducted to determine effects of AA on these soil properties and nutrient availability. In Experiment 1, three soils that ranged from 12 to 42% clay and 2.6 to 4.6% organic matter were packed moist into 15-cm long and 5.0-cm diameter columns. Soil columns were injected with reagent grade ammonium hydroxide solution (1931 mg N)at a depth of 0.5-cm below the soil surface at the top end of each column. Columns were incubated at 25°C and some were sampled at each of 1, 7, 28, and 112 days after injection. Sampling involved removing four 1-cm segments from the top of a column (depths 1 to 4) and a 1-cm segment from the bottom of the column (depth 15) for analysis. Experiment 2 was similar to Experiment 1 except that it involved only one soil, 129 mg N injected, and samplings at 1, 7, and 28 days.

Concentrations of exchangeable NH_4-N in Experiment 1 were uniform throughout the columns by day 7 and changed little to day 112. On day 7 they ranged from 1007 to 1660 mg kg^{-1}, which is similar to maximum expected concentrations in the NH_3 retention zone at usual field rates of application of AA. Maximum pH values were 8.8 to 9.2 and pH remained above 8.0 by day 112. Concentrations of water-soluble organic C increased to day 28, and then decreased to day 112 apparently because of microbial assimilation and dissimilation. Production of carbon dioxide from the soils was not detected until day 28 or later. Wet aggregate stability was initially decreased by ammonium hydroxide and then largely regained when microbial activity resumed. Ammonium hydroxide seemed to cause an increase in available P of 21% in one soil, and a decrease in available K of 3 to 14%.

On day 1 in Experiment 2, NH_4-N ranged from 760 mg kg^{-1} in depth 1 to 5.9 mg kg^{-1} in depth 15., while pH ranged from 8.6 to 6.9. Nitrification caused a continual decrease in NH_4-N to day 28, when pH was about 5.2 for all depths. Concentrations of water-soluble organic C did not significantly vary with depth and decreased from 627 mg kg^{-1} on day 1 to 380 mg kg^{-1} on day 28. Between days 7 and 28, wet aggregate stability increased while water-dispersible clay decreased for all depths.

It was concluded that AA could cause an initial loss of wet aggregate stability in the NH_3 retention zone, but this loss is likely to be regained when microbial activity resumes. Possibility of leaching of water-soluble organic C from the NH_3 retention zone by rainfall or irrigation, and long-term changes in microbial populations, might prevent regaining of structural stability under field conditions.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

EFFECTS OF MANAGEMENT ON SOIL HYDRAULIC PROPERTIES:

FINAL REPORT

September, 1990

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On Behalf of:	AGRICULTURE CANADA RESEARCH STATION, HARROW, ONTARIO N0R 1G0
In Cooperation with:	ONTARIO MINISTRY OF THE ENVIRONMENT Research Advisory Committee Dr. J. Eddie (Scientific Liaison)
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EXECUTIVE SUMMARY

A new and particularly useful field instrument, the Guelph Pressure Infiltrometer has been developed for determining insitu measurements of soil hydraulic properties. The objectives of this study were to assess the effects of management on changes in surface hydraulic properties. Specific objectives were:

1. To further test the relationship between rainfall runoff (from rainfall simulation experiments) and predicted runoff using measurements of K_{fs}, ϕ_m, $\Delta\theta$, and Tp from the pressure infiltrometer.

2. To examine the temporal changes in hydraulic properties measured with the pressure infiltrometer under two tillage systems and compare them to temporal changes in surface runoff (simulated).

3. To examine the effects of different cropping/tillage systems on changes in surface hydraulic properties.

Measurements were taken on 5 Tillage-2000 sites and also at the Elora Research Station, Univ. of Guelph. At the field scale sites, paired benchmarks were selected to cover the major soil and topographic changes in the field. A pressure infiltrometer attachment for the Guelph permeameter was used to obtain measurements of field saturated hydraulic conductivity K_{fs} and matric flux potential ϕ_m on each of the tillage/soil landscape combinations. Undisturbed soil cores were taken to determine bulk density, total porosity, saturated hydraulic conductivity, moisture retention curves, and an estimate of macro-porosity.

At three of the T2000 sites rainfall simulation studies were also carried out as part of a Ministry of Environment project. The rainfall simulation trials gave steady runoff, infiltration rates, and soil loss rates to compare to the pressure infiltrometer and undistrubed core measurements. Detailed measurements at three times during the year were taken at one of the sites (D. Lobb's).

The detailed measurements at D. Lobb's site indicated that no-tillage (9 yrs) resulted in;

1. higher bulk density
2. lower total porosity
3. lower macro-porosity
4. lower saturated hydraulic conductivity

5. lower field saturated hydraulic conductivity
6. lower matric flux potential
7. shorter times to ponding and runoff, and
8. lower infiltration rates (higher runoff)

compared to a moldboard treatment. The results were consistent across all measurement times. Similar effects of no-tillage compared to a minimum tillage treatment were also observed at a second site. No significant differences between no-till and other tillage systems were found at the remaining sites. Comparisons of minimum tillage and moldboard tillage treatments also indicated no influence of tillage on surface hydraulic properties.

At every site where both rainfall simulation and Guelph pressure infiltrometer measurements were taken, the data from both methods were comparable. Thus, the pressure infiltrometer should be a reliable, cost effective instrument for evaluating management effects on hydraulic properties. The portability and minimum site disturbance of the permeameter make it a good choice for small plot experiments.

The data suggest that there is a risk of increased surface runoff on no-tillage plots. The main factors resulting in decreased soil loss in no-till appear to be increased surface protection and decreased particle detachment, not decreased runoff. The risk of increased surface water runoff may be significant for the movement of non-adsorbed chemicals or soil additions (such as manure).

The increased runoff and decreased infiltration rates in the no-till does not support the hypothesis that no-till increases the risk of movement of chemicals to the groundwater.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

STUDIES ON THE CONTROL OF PROBLEM WEED SPECIES IN CONSERVATION TILLAGE SYSTEMS

FINAL REPORT

September, 1990

Prepared by:	SOUTHWESTERN ONTARIO AGRICULTURAL RESEARCH CORPORATION (SWOARC), Harrow, Ontario
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Disclaimer:	The views contained herein do not necessarily reflect the views of the Government of Canada or the SWEEP Management Committee.

EXECUTIVE SUMMARY

Conservation tillage systems have been advocated as a means of reducing soil erosion and phosphorous run-off from cropland, and of maintaining long-term soil productivity. Conservation tillage has been defined as any method of tillage which leaves a minimum of 30% residue on the soil surface. Such systems range from strict no-till to chisel plowing, but all involve a reduced frequency of tillage and/or a different type of tillage compared to conventional systems. One of the main obstacles to widespread adoption of conservation tillage is the perception by farmers that new and exacerbated weed problems will occur when tillage is no longer available as a method of weed control. To address this concern a study was undertaken to determine what weed problems resulted from a reduction in tillage, and to examine possible management strategies to handle these problems.

A survey was conducted to examine weed species composition and weed density in 593 farm fields across southwestern Ontario in 1988 and 1989. The crops selected for the survey were corn, soybeans and winter wheat. Tillage systems were categorized as conventional (including some form of soil inversion as by a moldboard plow), conservation (including some soil disturbance other than inversion), and no-till (no tillage between the current and previous crop). Fields were also grouped according to the length of time that a given tillage system had been practised.

In general, the same weed species were found in all tillage systems, but their frequency of occurrence and density varied slightly. All three tillage types were dominated by five weed species that occurred in more than 25% of fields: green foxtail, lamb's-quarters, redroot pigweed, common ragweed, and quack grass. Dandelions also occurred in more than 25% of conservation and no-till fields, as opposed to 21% of conventional fields. No-till and conservation tillage fields had higher overall weed densities than conventional fields. Weed populations varied greatly within tillage systems.

Only a few trends with length of time in a tillage system were observed. First year conservation tillage fields generally had more green foxtail and dandelions than conventional fields, but these weeds decreased once conservation tillage was established. Quack grass decreased in frequency and density with time in no-till or conservation tillage. Established no-till and conservation fields had markedly less quack grass than conventional fields.

Reduced tillage systems present an altered environment for weed growth and so may affect the rate of development of weed species. Most weed control practices are targeted at particular growth stages. The growth and development of the more common weed species were monitored in a small subset of the surveyed fields in 1989. Lamb's-quarters, redroot pigweed, and velvetleaf showed no difference in the timing of various growth stages among tillage systems. Green foxtail and common ragweed emerged later in no-till than in conventional tillage, and so may have been more likely to escape control. Perennial species emerged at about the same time in all tillages, but grew more slowly in conventional tillage than in no-till. Dandelion was the only weed to show a difference in flowering in relation to tillage. Dandelions flowered most often in no-till fields and least often in conventional fields.

Herbicide use patterns did not vary substantially among tillage systems, other than the increased use of burndown treatments, and decreased use of soil incorporated chemicals in no-till. The literature on herbicide efficacy in reduced tillage systems is not conclusive. The primary concerns of farmers in the study were 1) lack of information on dandelion control, and 2) the limited number of herbicides registered for burndown applications.

Greenhouse experiments were conducted to determine the effects of simulated "tillage" treatments on the survival of seeds, vegetative propagules, and actively growing plants of the more common weed species. Burial of weed seeds in the autumn, as through plowing, favoured annuals over perennials. Overwinter survival of roots and rhizomes of perennial species was decreased if they were brought to the surface. Mechanical damage to the roots of actively-growing annual weeds was an effective control method at all growth stages. Perennial species were susceptible to mechanical damage only over relatively short periods of time.

The results presented here show that problem weed species were not substantially different in different tillage systems. Weed communities were influenced by geographic region, soil type, field history and level of management, in addition to tillage. It is probably not appropriate to design a single strategy for weed management in reduced tillage systems.

The perception that weed management is more difficult in reduced tillage needs to be challenged. Changes in weed communities are small. Some changes offer a greater challenge for weed control; other changes offer opportunities for improved weed control. The transition to conservation tillage or no-till however may initially require more intensive weed management.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

EFFICIENCY OF RESIDUE MANAGEMENT FOR PROVIDING OPTIMAL CORN GROWING CONDITIONS IN A NON-TILLED SANDY LOAM

FINAL REPORT

March, 1991

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EXECUTIVE SUMMARY

No-till corn production is a soil conserving system that presents several challenges in terms of crop performance. The presence of crop residues on the soil surface results in many changes of physical, chemical and biological nature. These changes concern mainly soil temperature but also, soil water content, nutrient availability and phytotoxicity. In order to distinguish between residue effects on corn due to low soil temperatures from other residue effects, corn development was related to soil temperature for eight different types of residue covers: grain corn, spring canola, spring barley, spring barley and red clover killed early or killed late, soybean, soybean and fall rye killed early or killed late. Analysis shows that only corn plants growing in canola residues may have been delayed by a factor other than soil temperature.

The changes in soil temperature result almost invariably in delaying development of a corn crop when residue-covered soil is compared to a bare soil. The objective of another study was to determine if clearing the residues off the row in the interrow could alleviate the problem and improve the water status of a droughty soil. This management study showed that half of the delay (5 days) due to the presence of residues on the no-till plots could be avoided by clearing the residues off the row. This practice did not have much effect on water content when the plants had attained a large size. Two hybrids previously rated well and less-well suited for no-till production in 1988 in Huron county were used in the study. The hybrid rated less-well suited for no-till production yielded more grain per plant than the other hybrid. These hybrids were also used in another study designed to address the problem of uneven plant emergence and final establishment in no-till corn production. This problem is due to changes in surface properties of no-till compared to conventional tillage. There was a need to measure the variability of emergence and try to correlate it to some selected soil properties. The soil properties studied were soil water content, bulk density and seed depth. Bulk density was negatively correlated to emergence in conventional plots and water content was negatively correlated to emergence in no-till plots. The emergence of the hybrid rated less well-suited for no-till production in 1988 was less variable and less sensitive to seed zone environmental conditions than that of the hybrid rated well-suited for no-till production.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

PROCESSES INVOLVED IN MOBILIZATION OF PHOSPHORUS IN DIFFERENT FARMING SYSTEMS IN SOUTHWESTERN ONTARIO: NUTRIENT LEVELS IN PLANT TISSUES AND SOILS

FINAL REPORT

March, 1991

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Under the Direction of:	ECOLOGICAL SERVICES FOR PLANNING LIMITED, Guelph, Ontario - Subprogram Manager For TED
On Behalf of:	AGRICULTURE CANADA RESEARCH STATION, HARROW, ONTARIO N0R 1G0
Disclaimer:	The views contained herein do not necessarily reflect the views of the Government of Canada or the SWEEP Management Committee.

EXECUTIVE SUMMARY

The effects of the application of different types of phosphorus-containing fertilizers (rock P, super phosphate and compost) were examined on six different farms in order to identify some of the critical parameters for the mobilization of phosphate. The farms (three organic and three conventional) provided a gradient of conditions ranging from long-term organic to moderately intensive conventional. Three other experiments examined how crop, soil, and residue management practices on a long-standing organic farm affect mobilization of native and applied phosphate. The main findings of these four experiments are summarized below:

(1) RESPONSES TO DIFFERENT PHOSPHORUS FERTILIZERS IN ORGANIC AND CONVENTIONAL FARMING SYSTEMS

Two methods of extracting soil P were compared:anionic resin and sodium bicarbonate. A significant positive correlation between the two extraction methods was found. However, only the resin extraction method was sensitive enough to detect statistically significant differences between the fertilizer treatments.

Applications of super phosphate and compost each resulted in significant higher ($p < 0.05$) soil P (resin) than in controls in 3 out of 9 comparisons. On all farms, the values for soil P (resin) in compost and super phosphate treatments were numerically higher than those in controls. There was no statistically significant response to rock P.

Percent of P in one month old barley plants was significantly correlated with soil P (resin). There was no correlation of percent the percent of P in barley leaves at the heading stage with soil P. Over all farms, barley grain yields were significantly correlated to the percent of P in one month old plants. However when farms were considered individually this correlation was not always significant.

Percent of P in barley plants was not significantly affected by the fertilizer treatments except in one organic farm. Grain yields were significantly affected by the treatments only in one (conventional) farm.

Mycorrhizal infection tended to be lower on the super phosphate treatment on all farms. There was no indication that the percent of mycorrhizal infection was highest on the organic compared to the conventional farms. Similarly, there was no indication of either root or soil phosphatase activities being higher in one of the two types of farms.

(2) EFFECT OF THREE TILLAGE/STRAW TREATMENTS ON SOIL P AND CROP NUTRITION.

Three tillage treatments were imposed on a field after barley was harvested: mouldboard ploughing, discing, both with barley straw removed and discing with barley straw retained. In the second year three P containing fertilizers (as in experiment 1) were superimposed on the main tillage treatments. Soil fertility and nutrient contents of two different crops that followed these treatments were examined.

The disk + straw treatment increased soil P (resin) one year after the tillage treatments were imposed. As in experiment 1, no significant differences were found when soil P was extracted with sodium bicarbonate. Grain yields of maize, soil phosphatase activity and P concentration in maize grains were also higher under the disc + straw treatment. Compost and super phosphate increased soil P but no effect of rock phosphate was observed.

Our data indicates that the tillage/straw regime by itself can improve P nutrition.

(3) EFFECTS OF GREEN MANURING AND ROCK PHOSPHATE ON P NUTRITION OF DIFFERENT CROPS

Different green manures (faba beans, oil seed radish, buckwheat and weeds) were established in plots that had received 0 or 180 kg P_2O_5/ha as rock phosphate.

Rock phosphate increased soil P(resin) levels in 1988 and 1989. Green manures had no effect on increasing the levels of soil P when rock P was applied. Oat plants accumulated more Ca when buckwheat was the previous crop.

(4) EFFECTS OF CARBON ADDITIONS ON NITROGEN FIXATION AND P NUTRITION OF HAIRY VETCH AND FOLLOWING CROPS.

Three levels of oat hulls (0, 5, 10 t/ha) were incorporated into the soil with two levels of rock phosphate (0 and 180 kg P_2O_5/ha) and hairy vetch planted in the summer of 1989. In 1990, maize was planted and the residual effects of 1989 treatments monitored.

Both levels of oat hulls significantly decreased levels of soil nitrate in june 1989, improved nitrogen fixation (acetylene reduction) and vetch biomass production as well as decreased weeds. Total uptake of N, P, K, Ca was improved by the addition of oat hulls. The amount of nutrients carried into the system by the oat hulls were smaller than the surplus of nutrient accumulated in vetch biomass under the effect of 5 t oat hulls/ha. This indicate that oat hulls stimulated growth by a mechanism other than addition of nutrients.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

INVESTIGATION OF SOIL AND CROP RESPONSE TO FALL SUBSOILING IN SOUTHWESTERN ONTARIO

FINAL REPORT

August, 1991

Prepared by:	CAN-AG ENTERPRISES, Guelph, Ontario
Under the Direction of:	ECOLOGICAL SERVICES FOR PLANNING LIMITED, Guelph, Ontario - Subprogram Manager For TED
On Behalf of:	AGRICULTURE CANADA RESEARCH STATION, HARROW, ONTARIO N0R 1G0
Disclaimer:	The views contained herein do not necessarily reflect the views of the Government of Canada or the SWEEP Management Committee.

EXECUTIVE SUMMARY

Subsoil compaction is considered to be a serious problem in southwestern Ontario. Based on inspections of seventy fields chosen at random, approximately 15% and 45% of the clay to clay loam soils in five Counties in the southwest were found to be severely and moderately affected, respectively (Can-Ag Enterprises Ltd., 1988). The same study found corresponding crop yield declines to be some 25% and 12.5%, based on farmers reported yields for the fields inspected.

In 1988 a group of farmers initiated subsoiling experiments to examine corn response to interrow subsoiling in mid June. Can-Ag Enterprises Ltd. was contracted to monitor soil conditions and crop response. It was a very dry year and significant crop yield increases occurred on only two of the thirteen fields. These two fields had severely compacted soils: others were rated moderately compacted. A lack of response on moderately compacted soils was attributed to increased droughtiness following subsoiling and below average rainfall.

The current study commenced in the fall 1989, involving fourteen different fields but not all of the same farmers. Its objective was to determine the impact of subsoiling to a depth of about 30 cm after wheat harvest on subsequent crop yields. Three subsoiling implements were used in the research: Tye Paratill®; Strohm aerator®, and B.C. Sub-mulcher®. Field length strips (0.5 - 1 km long and 10 or 20 metres in width), two replicates each, were established to monitor effectiveness of each implement and a control.

Soils in each strip were examined to determine the degree and characteristics of compaction shortly after subsoiling in 1989 and again after the 1990 harvest. Measurements included hand and cone penetrometer readings, soil bulk densities on control plots, and detailed visual inspections of structure and pores. At a few fields, bulk densities were determined on all treatments.

The 1990 crop yields were measured by the farmers. They harvested each strip separately and used weigh wagons to determine yields. Farmers also shared their experience with respect to workability of the soils, ponding following rains, and their evaluation of the degree of compaction. In addition, they monitored all inputs including field operations, type of equipment used, fertilizer and herbicide inputs, and general crop performance during the growing season.

Statistical analyses were conducted to determine significant differences in crop response and soil conditions to the treatments. Also a Pearson correlation matrix was used to identify significant correlations among various soil parameters, management inputs, and crop yields.

Results indicated significant changes in soil conditions to the different subsoilers, however, only two fields produced a substantial crop yield increase. Considering all plots as a group, there was not a significant yield response in 1990 to the fall 1989 subsoiling. Moisture conditions throughout the 1990 growing season were good, seldom being too wet or too dry.

Soil compaction was rated moderate on eleven fields, slight to moderate on one, and moderate to severe on two. Twelve of the fields were clayey, specifically, clay loams, silty clays and silty clay loams. The other two were sandy loams.

The Paratill® was the most effective implement in reducing soil compaction and soil differences remained visible and measurable in the fall 1990. The Strohm aerator® appeared to be slightly, but not significantly, more effective than the B.C. Sub-mulcher®.

Measurements of fuel consumption per hectare indicated highest requirements for the Strohm aerator® followed by the Paratill®, and then the B.C. Sub-mulcher®. The Paratill® required the highest draught followed by the Strohm aerator® and the B.C. Sub-mulcher®. This apparent anomaly is possibly due to malfunctioning draught pins in the computerized tractor providing questionable numbers. The lack of any wings on the shanks of the B.C. Sub-mulcher® makes it easiest to pull even though it had more shanks and was wider than the other subsoilers.

Examination of management inputs complicates interpretation of the results. Four farmers fall plowed their fields in 1989 (after subsoiling) as deep as they were subsoiled. This was their normal practice, perhaps a substitute for subsoiling. One of these fields was moderate to severely compacted, while the others were moderately compacted, all being clayey soils. A lack of yield response on these fields may therefore be due to deep plowing eliminating the effects of subsoiling. Of the two fields where good yield responses in soybeans were measured on the Paratill® treatments, on moderately compacted clayey soils, one was no-till the other was conservation tillage. Correlation analyses indicated a positive relationship between yields and soil fertility levels.

A lack of more noticeable yield responses in 1990 may be due to the relatively favourable moisture conditions through the growing season, even though soil conditions appeared to benefit from subsoiling. Furthermore, the fact that most of the sites were moderately compacted made it difficult to relate responses of yield to degree of compaction.

In the literature, mixed responses to subsoiling were reported. Our studies indicated that compacted subsoils were widespread, however, crop responses to subsoiling have not been clearly predictable nor measurable. First, longer term studies are essential to encompass weather variability. To save costs, farmers should confine subsoiling to severely compacted sites until more is known about crop responses to subsoiling. Of the implements used, the Paratill® is considered to be the most effective subsoiler, keeping in mind that this is based on one year of data from four fields. In the heavy clay soils, tillage practices such as deep plowing or chiselling are also considered effective in ameliorating compaction at the 15 to 30 cm depth. Farmers should also be aware of other management practices which tend to alleviate soil compaction. These include:

- reduction in vehicle weights (axle loads),
- avoiding working on wet or very moist soils,
- limiting the number of passes over the field, especially if moist, and
- utilizing cropping systems and rotations which facilitate the above and provide crops with deep rooting action as well as maintain or improve soil organic matter content.

On severely compacted soils subsoiling may be viable, however, farmers should establish trials first to determine whether there is a significant and economical yield response. Adoption of the above mentioned practices is also advised to reduce re-compaction of the soils likely to occur in one or two years.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

THE DEVELOPMENT AND TESTING OF A DRY FERTILIZER PLACEMENT MACHINE

FINAL REPORT

August, 1991

Prepared by:	ALBIN-TILL-TECH JOINT VENTURE, St. Thomas, Ontario
Under the Direction of:	ECOLOGICAL SERVICES FOR PLANNING LIMITED, Guelph, Ontario - Subprogram Manager For TED
On Behalf of:	AGRICULTURE CANADA RESEARCH STATION, HARROW, ONTARIO N0R 1G0
Disclaimer:	The views contained herein do not necessarily reflect the views of the Government of Canada or the SWEEP Management Committee.

EXECUTIVE SUMMARY

The objective of this project was to develop a machine which would provide farmers practising conservation tillage with the means to apply dry form nitrogen sources (ie. urea and/or ammonium nitrate). Before the project began, the standard nitrogen source used in reduced tillage systems was liquid 28% N which was applied by an applicator developed to inject the material into the soil.

From an environmental perspective, the benefits of the prototype machine (hereafter referred to as fertilizer zone-tiller) are seen as follows:

* the environmental risks associated with storage are lower with dry forms (urea and ammonium nitrate) than with liquid 28% N or anhydrous

* the fertilizer zone-tiller works effectively in no-till applications and in varied soil types (tested in sandy loam and clay loam soils). The coulter design cut previous-crop residue for accurate fertilizer placement while leaving trash between the rows for continued soil protection from wind and water erosion.

* the fertilizer zone-tiller can be pulled in tandem with the planter thus reducing: 1) fuel consumption and, 2) field passes (risk of soil compaction is less)

The criteria for judging the success of this project were established as follows:

If corn fertilized using the fertilizer zone-tiller performed[1] at least as well as corn fertilized with the liquid 28% N applicator,

then, the fertilizer zone-tiller is a feasible fertilizer placement machine.

If comparable or better results can be achieved using dry nitrogen fertilizers (vs. 28% N), then, conventional farmers who favour their use might be more inclined to convert to soil conservation cropping techniques.

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[1] Evaluation parameters - yield, biomass, height and nitrogen uptake

To establish whether the fertilizer zone-tiller has merit, it were tested over two years with two plots on a sandy loam site (1989, 1990) and one plot at a clay loam location (1990). While corn at the clay loam location did not show a response to nitrogen, good data were collected over two years at the sandy loam site. Results from the latter site are summarized below:

Year 1 - urea vs. liquid 28% N

- liquid 28% N showed a slight advantage over urea though the yield difference was not statistically significant

Year 2 - dry fertilizer (20% ammonium nitrate + 80% urea)
vs. liquid 28% N

- the dry fertilizer combination outperformed both liquid 28% N treatments (with and without coultering) by a significant 747 kg ha$_{-1}$ and 1158 kg ha$_{-1}$ respectively

In year 2, ammonium nitrate was applied to all dry fertilizer treatments at time of planting. The timing of urea application was varied according to the original testing procedure.
Starter fertilizer comprised of phosphorus and potassium was applied to plots based on soil test recommendations taken each year.

CONCLUSION

With the fertilizer zone-tiller performing *at least as well* as the liquid 28% N applicator, the data clearly suggests that it is a viable alternative in conservation tillage systems.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

THE USE OF KELP AND MOLASSES IN AN AERATION TILLAGE SYSTEM

FINAL REPORT

July, 1991

Prepared by:	CONSERVATION MANAGEMENT SYSTEMS A Division of ECOLOGISTICS LIMITED, Lucan, Ontario
Under the Direction of:	ECOLOGICAL SERVICES FOR PLANNING LIMITED, Guelph, Ontario - Subprogram Manager For TED
On Behalf of:	AGRICULTURE CANADA RESEARCH STATION, HARROW, ONTARIO N0R 1G0
Disclaimer:	The views contained herein do not necessarily reflect the views of the Government of Canada or the SWEEP Management Committee.

EXECUTIVE SUMMARY

The Use of Kelp and Molasses in an Aeration Tillage System

In 1989 and 1990 two field trials were carried out each year in Oxford County to determine the effects of kelp, molasses and 71B fertilizer solution (1990 only) on soybean plant growth and seed yield in an aeration tillage system.

Results from two years of study indicate that the use of kelp and/or molasses and/or 71B fertilizer solution as a seed and/or foliar treatment in an aeration tillage system did not significantly affect the growth and yield of soybeans.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

CEREAL COVER CROP STUDY

FINAL REPORT

July, 1991

Prepared by: CONSERVATION MANAGEMENT SYSTEMS
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Under the Direction of: ECOLOGICAL SERVICES FOR PLANNING LIMITED,
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Disclaimer: The views contained herein do not necessarily reflect the views of the Government of Canada or the SWEEP Management Committee.

EXECUTIVE SUMMARY

The Effect of Crop Species and Method of Planting of a Cereal Cover Crop on the Growth and Yield of Corn

During 1987-1989 four trials were conducted in Middlesex and Huron Counties, in southwestern Ontario to study the effect of cereal crop species (rye, barley, oats) and method of planting on the growth and yield of no till planted corn. The methods of planting included broadcasting the seed at soybean leaf drop, broadcasting the seed at soybean harvest, tilling the soil and drilling the seed into soybean residue and a control where no seed was planted. Excess rainfall during the fall of 1987 and 1988 and drought during late spring of 1988 affected the performance of the cover crops and main (corn) crop. Results from two years of study indicate that winter rye, spring barley and spring oats seeded at soybean leaf drop or at harvest increased soil residue cover when compared to soybean stubble alone, through winter and early spring. Barley and to a lesser degree, oats, seeded at harvest followed by seeding at leaf drop achieved the best corn growth and yield. Practical considerations related to labour needs, weather and the timing of cover crop establishment for adequate fall growth do not favour the planting of cereal cover crops at or after harvest.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

THE EFFECT OF SPLIT APPLICATIONS OF NITROGEN ON CORN YIELD UNDER RIDGE AND NO-TILL CONDITIONS

FINAL REPORT

October, 1991

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Disclaimer:	The views contained herein do not necessarily reflect the views of the Government of Canada or the SWEEP Management Committee.

EXECUTIVE SUMMARY

Trials were carried out on two farms in Huron County to examine the relative merits of splitting the timing of the application of nitrogen fertilizer between planting and sidedress applications. Current findings have been that in southwestern Ontario sidedress applications of nitrogen have a yield advantage over preplant applications. Thus more nitrogen must be applied if the total season application is applied on or before the date of planting, relative to where a large portion of the nitrogen is applied later in the season, closer to the time of consumption by corn.

The experiments involved applications of 0, 20 and 40% of the seasonal application of nitrogen at the time of planting, with the remainder of the nitrogen sidedressed. Trials were carried out in each of a no-till and ridge-till system.

There was no evidence from these trials to support the practice of splitting nitrogen applications or for the application of the entire season's nitrogen at sidedressing. However, in light of this study having been limited to one year's data collection, further testing may be warranted to more thoroughly examine the relationship of nitrogen timing and crop nutrition and grain yields.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

THE EFFECT OF ORGANIC MULCHES ON SOIL MOISTURE AND CROP GROWTH

FINAL REPORT

August, 1991

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Under the Direction of:

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EXECUTIVE SUMMARY

Many of the advantages of the conservation tillage systems currently in use derive from the presence of crop residue on the soil surface. Crop residues reduce soil erosion losses, therefore increase soil water infiltration, and decrease soil water loss by evaporation (Griffith et al., 1986).

Additionally, crops can be grown specifically for the purpose of covering the soil during periods between main crops, to then be killed and left as a mulch on the soil surface before planting of the main crop. The management practices used in the spring will then influence the value and effectiveness of cover crops (Triplett, 1986).

The timing of killing of the cover crop is a critical decision dependent on climate. Adequate amounts of mulch have to be present after killing, to assure that the soil water conserving properties of the mulch are maximized. On the other hand, delay in the timing of killing can have adverse effects on subsequent crop growth if soil water is limiting, such as during a dry spring or on soils with low water holding capacity. During a wet spring, the possibility of removal of excessive moisture by the growing cover crop suggests that a late killing could allow the timely planting of the main crop.

In addition to the soil water conserving properties of a mulch, effects such as a decrease in soil temperature variations can be a advantage for the growth of the subsequent crop, and should be considered in the management practices of the cover crop.

Winter rye is among the cover crops extensively used due to its winter hardiness, low fertility tolerance, early spring growth and persistence of the mulch produced (Moschler et al., 1967). In this study, soybeans were chosen as a standardized main crop and winter rye was used as the preceding cover crop on a sandy, a loam and a clay soil.

The use of a model linking climate to the effect of a rye mulch on soybean growth would be very useful in determining optimum management of the cover crop for various weather scenarios.

Therefore, the main research objectives of this project were:

1) to study the timing of rye killing in a rye/soybean system, where the rye is planted in the fall, chemically killed and mowed in the spring, and soybeans are no-tilled through the rye mulch;

2) to investigate the effect of a rye mulch on soybean growth and yield;

3) to measure the effect of rye mulch on soil water and soil temperature.

4) to model the effect of a rye mulch on soybean growth under various spring weather scenarios.

The rye mulch/soybean system studied proved satisfactory for soybean production on a sandy and a loam soil. On a clay soil, difficulties associated with excess fall moisture and winter kill interfered with cover crop establishment, while planter problems and slug damage in the spring decreased soybean yield on mulched plots. More research would be necessary if the system is to be adapted to clay soils, but our experience was not encouraging.

On the sandy and the loam soil site, rye mulch amount was significantly larger for the late killing date as opposed to an early killing date. Differences between soil drying rates under early killed rye mulch and late killed rye mulch were observed in 1990 at Delhi, but generally soil water content between the two mulch treatments was not different. Soil water conservation under mulch, although significant for short periods early in the season during one year, did not affect early soybean growth due to timely rainfalls.

For rye mulch amounts larger than 2000 kg/ha, no significant increases in percentage ground cover were gained by delaying rye cover crop killing. Also, mulch decomposition proceeded at a faster rate for large mulch amounts.

Although the rye mulch had a significant effect on the soil surface drying rate early in the soybean growing season, shading of the soil surface by the soybean canopy plus a substantial decrease in the amount of mulch present on the soil surface, resulted in little difference between mulch and no mulch conditions later in the season.

Analysis of hourly soil temperatures measured under mulch and no mulch treatments revealed that extreme temperatures are more frequent under the bare soil condition. Over the whole growing season these differences were limited to a small percentage of hours, but the lower variability of temperature under the mulch may have benefited microbial activity and root growth slightly.

The change in the moisture and temperature regimes of the soils studied, induced by the presence of a rye mulch on the soil surface, did not result in significant soybean yield increases or decreases. Delays or decreases in soybean emergence observed for some treatment-years were compensated by the plants as the seasons progressed. If other beneficial aspects of the no-tillage system are considered, such as reduced soil erosion (Phillips et al., 1980), and, weed suppression (Weston, 1990), rye mulch is recommended to be used in no-till soybeans.

The simulation of soybean growth in Southwestern Ontario by the SOYGRO model proved satisfactory after genetic coefficients were obtained for the soybean varieties used in our field experiments.

Simulated soil water contents under bare soil were close to measured values, and the mulch effect on soil water was well described by a simple empirical equation.

The drying effect of a growing rye cover crop was not considered in this simulation. This was not an important factor in our field trials either, but could be during a very dry spring. Also, field and modelling experience have shown that a large amount of mulch is needed to positively influence yield. The feasibility of producing such large amounts of rye before soybean planting has not been thoroughly considered. Practical aspects such as soybean planting through large amounts of residue were also not considered. Nevertheless, the examples presented here demonstrate how SOYGRO can be coupled to submodels that predict the effect of mulch on soybean growth.

For a complete modelling of the rye/soybean system studied it is necessary that a more comprehensive mulch model, and a rye growth model be coupled to the SOYGRO model. Work is under way to accomplish this integration and will be reported in C. Wagner Riddle's Ph.D. Thesis.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

THE RESPONSE OF SOIL MICROFLORA AND FAUNA TO SPRING PLOWING OF ZEROTILL AND PASTURE SOILS

FINAL REPORT

October, 1991

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Disclaimer:	The views contained herein do not necessarily reflect the views of the Government of Canada or the SWEEP Management Committee.

Executive Summary

The purpose of this study is to use populations of soil organisms to contrast ecosystem stability in an undisturbed pasture with a zerotill winter wheat field. Soil organisms that were considered include soil microbial biomass, nematodes, earthworms, soil dwelling arthropods, cryptozoic invertebrates, and emergent arthropods. The pasture represents a more natural ecosystem as it is undisturbed agriculturally, and the zerotill field represents an actively managed agroecosystem.

Stability was measured by perturbing the populations of soil microflora and fauna by plowing and disking the soil, and measuring their time to return to, deflection from, and rate of return to, the ground state. Return time was faster and deflection from ground state was less in the zerotill agroecosystem than in the pasture system. These results suggest that agroecosystems are not unstable, as communities within the agroecosystem can recover from perturbation. Diversity, as measured by richness and evenness, was similar in pasture and zerotill soil for those populations for which it was determined.

Litter decomposition rate (LDR) was measured using litterbags. LDR was faster in the zerotill plowed system compared to pasture plowed, possibly because of the more rapid return of macro-invertebrates in the plowed soil. Differences in soil microbial biomass do not appear to account for differences in LDR.

Saturated hydraulic conductivity (SHC) and dry bulk density (DBD) were used to measure pore continuity. In the zerotill system, SHC and DBD were significantly higher in the unplowed soil indicating that pore continuity is much higher in unplowed soil. In the pasture system, plowed soil had a higher SHC and a similar DBD to that of

unplowed soil indicating that pore continuity is higher in plowed soil, possibly because of the destruction of roots previously plugging the pores of unplowed soil.

Water infiltration rate was found to be correlated with the number of earthworms in pasture and zerotill unplowed and plowed soils. This illustrates the importance of bioporosity in these soils.

The recommendation to plow zerotill soils every 4-5 years is put into question by this study. The soil quality indicators of earthworm number, water infiltration rate and pore continuity indicate that plowing zerotill soil may not be beneficial. Chisel plowing or ridge tillage might be acceptable intermediates.

Number of mites and richness and abundance of soil dwelling arthropods were modelled against various environmental parameters. Cropping system (pasture or zerotill), depth, and organic matter content appear to strongly influence the distribution of soil dwelling arthropods. Tillage (yes or no), water content and wet bulk density were not as important determinants. Number of mites did vary with depth over the season, numbers increasing with depth in the plowed soil, and decreasing with depth in the unplowed soil. Mites returned to the upper levels of plowed soil when temperatures and vegetational growth returned to similar levels to that of the unplowed soil.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

FIELD SCALE TESTS OF THE MODIFIED MOLDBOARD PLOW

FINAL REPORT

October, 1991

Prepared by:	CONSERVATION MANAGEMENT SYSTEMS A Division of ECOLOGISTICS LIMITED, Lucan, Ontario
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Disclaimer:	The views contained herein do not necessarily reflect the views of the Government of Canada or the SWEEP Management Committee.

EXECUTIVE SUMMARY

The erosion of agricultural land and the associated pollution of Lake Erie with sediment and phosphorus have been identified as major agronomic and environmental problems in Ontario (1,2). Of the several methods available to control soil erosion and phosphorus movement conservation tillage systems are rated among the best (4). A need exists for a conservation tillage system that will maintain crop yield and provide adequate residue cover.

Fall weather conditions in Ontario can prolong harvest and fall primary tillage is often done in excessively wet soil. Under these conditions the moldboard plough has been and will likely continue to be the implement of choice for many farmers. The main problem in using the moldboard plough is that the implement tends to bury almost all residue from the previous crop. As a result the potential for controlling soil erosion is considered poor. Little work has been done to improve this performance.

This research project is a continuation on a field scale of initial work (10) carried out by Conservation Management Systems (CMS) in 1988 which looked at modifications to the shapes of three moldboard types (general purpose, high speed and European) mounted on three makes of ploughs (White®, John Deere® and Overum®) commonly used in Ontario. This project studied the residue management potential capabilities of different configurations of the modified moldboard as first used by Vyn, Daynard and Ketcheson (8,9).

The field scale modified moldboard trial (1989 - 90) was carried out at four different sites within the Lake Erie Basin. Each site was located in a grain corn stubble field with one site in each of Perth and Middlesex Counties and the two remaining sites situated in Kent County.

The trials were set up as a "modified" randomized complete block design consisting of three or four replications depending on the amount of room available within the cooperator's field. The treatments consisted of three modifications (cuts) to the moldboard shape and one control (full moldboard). At one site a Norcan Minibottom® was also included as a treatment.

Soil surface residue cover data were collected at four different dates within the project time frame. They included: before ploughing (fall '89); after ploughing (fall '89); after spring run-off (early spring '90), and after planting (spring '90). At all sites there was an average initial (before ploughing) residue cover of 80 percent or greater with little variation among sites.

Only one of the four sites (site 1) showed a definite increase in residue levels immediately after ploughing as more cuts were made to the moldboard while at the remaining sites there was no advantage to altering the shape of the moldboard with respect to residue levels. The cooperator at site 1 used a European type plough set at 40.6 cm bottom widths. Two of the three remaining cooperators (sites 3 and 4) used 30.5 cm bottoms on their European type ploughs which resulted in residue levels between 24 and 36 percent after ploughing. The remaining site (site 2) also used a European type plough but with 35.6 cm bottoms with residue levels ranging from 12 to 14 percent. The Norcan Minibottom® was also used at this site which left average residue level of 20.1 percent after ploughing.

At site 3 all four treatments left 20 percent or greater residue levels after spring run-off. Of the remaining sites, only two treatments at site 1 (2nd and 3rd cut treatments) left residue above 20 percent. The Norcan Minibottom® at site 2 plus the full moldboard and 1st cut treatments at site 4 recorded residue levels within 2 percent of the benchmark 20 percent required for soil erosion control.

The full moldboard treatment at site 4 was the only treatment to leave at least 20 percent residue after planting followed by the 1st cut treatment at 18.2 percent residue. These two treatments had residue levels significantly greater than the 3rd cut treatment at this site. At the remaining sites there were no differences among treatments with average residue levels of 13, 9.4 and 9.4 for sites 1, 2 and 3 respectively.

In this field scale study other variables such as depth of ploughing and soil texture appeared to also influence the level of residue left on the soil surface.

In general, there were no consistent significant differences among treatments in soybean plant growth, development and seed yield at the different sites.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

OPTIMAL HERBICIDE USE IN CONSERVATION TILLAGE SYSTEMS

FINAL REPORT

August, 1991

Prepared by:	J.E. Shaw, RIDGETOWN COLLEGE OF AGRICULTURAL TECHNOLOGY, Dr. C.J. Swanton, V.S. Malik, DEPT. OF CROP SCIENCE, UNIVERSITY OF GUELPH, Guelph, Ontario
Under the Direction of:	ECOLOGICAL SERVICES FOR PLANNING LIMITED, Guelph, Ontario - Subprogram Manager For TED
On Behalf of:	AGRICULTURE CANADA RESEARCH STATION, HARROW, ONTARIO N0R 1G0
Disclaimer:	The views contained herein do not necessarily reflect the views of the Government of Canada or the SWEEP Management Committee.

EXECUTIVE SUMMARY

The goal of this study was to develop weed control recommendations for farmers utilizing conservation tillage systems. Efforts were directed towards optimizing herbicide selection, dosage and timing of application in order to achieve effective weed control. Moreover, research was also conducted to optimize herbicide inputs by developing an integrated weed management system for no-till corn. An economic and risk management study of weed control measures was also completed.

The results of this study will provide weed control and specific crop recommendations for farmers using conservation tillage. This information will facilitate the acceptance of conservation tillage practices within the Ontario farming community.

Field experiments were conducted from 1987 to 1990 to address the specific objective outlined in this report. Our findings included:

1. Currently recommended herbicides and herbicide combinations provided excellent broad-spectrum weed control in all tillage systems tested.

2. Control of weeds in conservation tillage systems did not require higher dosages of herbicides despite the presence of crop residue on the soil surface.

3. Perennial weeds can be effectively controlled and should not pose a significant threat to successful crop production in conservation tillage systems.

4. The integration of banded herbicide applications, inter-row cultivation and reduced herbicide dosage can be integrated as a weed control alternative for no-till corn . Adoption of these practices can reduce the total amount of herbicide applied into the environment by 60%.

5. An economic comparison of alternative tillage systems and weed control practices among various tillage systems was completed. Optimum preemergence herbicide applications were identified for both corn and soybeans grown under four different tillage systems. The reductions in labour associated with the reduced tillage systems indicated that labour cost were reduced by up to 61% annually when compared with an conventional tillage systems. This saving in labour was illustrated as an opportunity cost associated with reduced tillage systems on sandy soils. A sensitivity analysis between moldboard plough and no-till indicated that no-till will dominate in risk preferring intervals, and an increase in no-till

net farm returns of \$ 40 ha^{-1} would change dominance in favour of no-till among risk averse individuals. It is possible for conservation tillage systems to dominate conventional tillage systems, if proper weed control and crop production techniques are undertaken.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

DEVELOPMENT OF A COMPUTER-BASED FARM DECISION SUPPORT FRAMEWORK
PHASE I

FINAL REPORT

October, 1991

Prepared by:	ROBBERT ASSOCIATES, Ottawa, Ontario
Under the Direction of:	ECOLOGICAL SERVICES FOR PLANNING LIMITED, Guelph, Ontario - Subprogram Manager For TED
On Behalf of:	AGRICULTURE CANADA RESEARCH STATION, HARROW, ONTARIO N0R 1G0
Disclaimer:	The views contained herein do not necessarily reflect the views of the Government of Canada or the SWEEP Management Committee.

Report on the Farm Management Framework Project Phase I

Robert Hoffman
Bert McInnis

April 23, 1991

1. Introduction

This is the final report on Phase I of the project undertaken by ROBBERT Associates as part of the Technology Evaluation and Development (TED) Sub-Program of the Soil and Water Environmental Enhancement Program (SWEEP). The project consisted of the design and implementation of a prototype computer based farm management simulation framework that can be used at the level of the individual farm to examine the impact of tillage and cropping decisions on soil quality, nutrient loss to runoff, and farm income. The objective was to determine whether modelling techniques might be useful to effect the transfer of technology from the scientific community to the farm.

2. Project structure

The project was carried out by Michael Hoffman, Robert Hoffman and Bert McInnis of ROBBERT Associates working with an advisory group consisting of Bob Fletcher, Dave Charlton and George Schell of Ecological Services for Planning, Don Lobb and Doug Smith both farmers, Wally Findlay of Agriculture Canada, and John Schleihauf from the Ontario Ministry of Agriculture and Food.

The project commenced in June, 1990 and was concluded in March 1991. The advisory group met on four occasions with ROBBERT Associates, July 13, 1990, November 29, 1990, March 27, 1991, and April 11, 1991. Both the April and March meetings involved interaction with the computer system.

A poster presentation was displayed at the TED - Tillage 2000 Conference held in London on March 4-5, 1991. A copy of the handout that accompanied the poster is appended to this report.

3. Structure of the Farm Management Framework

The structure of the Farm Management Framework (FMF) is documented in the FMF Manual, (Ref 10). The Farm Management Framework consist of fifteen calculators or independently executable submodels organized in a hierarchy composed of five major components:

- **Cropping** component that represents all aspects of crop production including soil productivity - crop relationships;
- **Livestock** component that represents all aspects of the production of dairy and livestock products;

- **Crop and Manure Balance** component that keeps track of the interdependence between cropping and livestock operations
- **Equipment** component that keeps track of the equipment needed for field operations and its utilization in terms of operator time and fuel
- **Farm Finance** component that represents the elements farm income and outlay separately for cropping and livestock operations and a capital expenditures account.

The full hierarchy is shown in Figure 1. The interdependence among the calculators is shown the Dependency Structure diagram, Figure 2.

The Framework is designed to simulate farm operations to a time horizon of fifty years from the present. Calculations are performed with a one year time-step.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

SURVEY OF MOISTURE DISTRIBUTION BETWEEN TILE DRAINAGE LATERALS AND ITS RELATIONSHIP TO COMPACTION AND ROOTING DEPTH IN FLAT CLAY SOILS

FINAL REPORT

December, 1990

Prepared by:	STRATA ENGINEERING CORPORATION Don Mills, Ontario
Under the Direction of:	ECOLOGICAL SERVICES FOR PLANNING LIMITED, Guelph, Ontario - Subprogram Manager For TED
On Behalf of:	AGRICULTURE CANADA RESEARCH STATION, HARROW, ONTARIO N0R 1G0
Disclaimer:	The views contained herein do not necessarily reflect the views of the Government of Canada or the SWEEP Management Committee.

EXECUTIVE SUMMARY

Three tile drained farms on flat, poorly drained Brookston clay soil in northern Essex County were studied with respect to soil moisture distribution between drainage laterals and its relationship to compaction, root growth, crop development, and yields. The survey type study was carried out under uncontrolled conditions in order not to interfere with the cropping program and schedule of the three farmer cooperators.

No significant increase in soil density (and hence compaction) was observed on one farm which had tomatoes in its rotation the year before the study. Mean dry densities were lower on this farm than on the other farms studied.

Information from this study suggests that a soil moisture content of 20%± represents optimum conditions for soil compaction on Brookston clay, and that agricultural equipment and implement traffic should be avoided at or near this moisture content, if possible. It was noted that soil moisture contents at harvest time are generally below 20%. Therefore, harvesting equipment and loaders for intensive cropping (tomatoes) should not pose a soil compaction problem on Brookston clay soil, unless there is a wetter than normal harvesting season.

Marked soil cracking was observed on all farms during the summer months. Principally because of these cracks, summer rains percolate very quickly below tile drain invert level. This tendency for relatively quick drainage during summer months is felt to be limiting adequate wetting of the root zone, and may also be contributing to undesirable removal of soil nutrients.

Due to the small number of farms and the overview scope of this study, firm conclusions could not be drawn for all parameters studied. Some observed trends require confirmation through further specific dedicated research, under controlled conditions, as outlined in the recommendations given in this report.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

NUTRIENT DISTRIBUTION AND STRATIFICATION RESULTING FROM CONSERVATION FARMING

FINAL REPORT

December, 1990

Prepared by:	ECOLOGISTICS LIMITED Waterloo, Ontario
Under the Direction of:	ECOLOGICAL SERVICES FOR PLANNING LIMITED, Guelph, Ontario - Subprogram Manager For TED
On Behalf of:	AGRICULTURE CANADA RESEARCH STATION, HARROW, ONTARIO N0R 1G0
Disclaimer:	The views contained herein do not necessarily reflect the views of the Government of Canada or the SWEEP Management Committee.

EXECUTIVE SUMMARY

Under conservation tillage systems using broadcast placement of phosphorus (P) fertilizers, there is a tendency for phosphorus to remain at or near the surface of the soil, resulting in vertical stratification. Band placement of P fertilizer in soils under conservation tillage may also lead to stratification of nutrients in a horizontal dimension.

In order to study the extent and severity of nutrient stratification in Ontario soils, a survey was conducted of the distribution of P and other nutrients, such as, Potassium (K), Magnesium (Mg) and Calcium (Ca) in a vertical and horizontal grid over a number of field conditions and management histories. The distribution of pH and organic matter and several soil physical properties (bulk density, cone penetrometer resistance, surface water infiltration) were also studied in relation to the distribution patterns of nutrients in the soil.

In the first of two experiments, a study of vertical stratification of nutrients, the effects of conservation tillage were compared with the effects of conventional tillage over a range of soil textural groups. At each of 36 sites, the soil was sampled at 2 cm increments to a depth of 20 cm, and below that at 5 cm increments to a depth of 45 cm. Samples were analyzed for plant-available P, K, Mg and Ca in addition to pH and organic matter. Soil physical property data (bulk density, cone penetrometer resistance and surface water infiltration) were also collected at each site.

A questionnaire was given to each farm cooperator requesting information regarding management history of the field. Based upon this information, the management of each field was classified as conventional tillage (CT), reduced tillage (RT) or notill (NT).

Nutrient data were grouped into three strata (0-10 cm, 10-20 cm and 20-45 cm) corresponding to expected average depths of secondary and primary tillage. The data within these strata were statistically summarized to determine means and regressed to find the slope over depth. The slope provided a relative index of change in nutrient concentration with depth and thereby an indication of stratification. The slopes of nutrient concentrations were analyzed for differences among tillage methods and soil types (clay, loam, sand). The stratum means of the measured soil physical properties and the gradient slope of organic matter were incorporated into the analyses. Questionnaire data were also included when possible.

Tillage systems had a significant effect on the vertical distribution of nutrients in the soil sampling layer. Soil under CT practices displayed a relatively even distribution of nutrients within the plough layer as indicated by a slower decline in nutrient concentrations with depth. Soil in fields managed under NT systems had a significantly greater rate of decline in nutrient concentration with depth. The lack of soil mixing resulted in an accumulation of nutrients at or near the soil surface. Soil organic matter content was similarly stratified with depth under NT conditions.

Soil texture was also a significant factor affecting the stratification of nutrients. Higher water infiltration rates associated with sandy soil enhanced the leaching of nutrients from the soil surface and reduced the development of a stratified surface layer by moving the nutrients down through the soil profile.

The second experiment was a study of horizontal distribution and stratification of soil nutrients, pH and organic matter over a range of soil textural groups. Nine sites were chosen for the study in fields which had been fertilized using a band application method and managed under a NT cropping system. Three sites were selected within each textural group: sand, clay and loam. As in the first experiment, a questionnaire was given to each farm cooperator requesting management history of the field.

At each location, a trench was dug along a 100 cm transect positioned perpendicular to the crop rows. Sample points were located every 20 cm along the transect starting at 0 cm giving a total of six points. The first point along the transect (0 cm) was always located within a crop row. Soil samples were taken by hand trowel at each transect point at 2 cm increments to a depth of 20 cm. These samples were analyzed for soil nutrient content (P, K, Mg, Ca) and pH. Similar samples to a depth of 16 cm were analyzed for organic matter content.

To identify horizontal stratification of nutrients, the standard deviations of the nutrient concentrations at each depth across the transect were determined. An analysis of variance was conducted on these results. A numerically high standard deviation was considered indicative of a relatively high degree of stratification or variance in concentrations across the transect.

The number of years that each field had been managed under a NT system was significantly related to the horizontal variation in nutrient concentrations; the severity of horizontal stratification of nutrients increased with the number of consecutive years under NT. Soil texture was a significant factor affecting the severity of horizontal stratification of K, Mg and to lesser extent, P. Only P stratification was significantly affected by the soil sample depth; the horizontal variation in P concentrations was greatest at 6 cm.

The results of the two experiments show that the stratification of nutrients in soils does exist, primarily within the soil sampling zone, and that its severity is directly related to tillage practice.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

RED CLOVER COVER CROP STUDIES
1987 - 1990

FINAL REPORT

January, 1992

Prepared by:	CONSERVATION MANAGEMENT SYSTEMS A Division of ECOLOGISTICS LIMITED, Lucan, Ontario
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On Behalf of:	AGRICULTURE CANADA RESEARCH STATION, HARROW, ONTARIO N0R 1G0
Disclaimer:	The views contained herein do not necessarily reflect the views of the Government of Canada or the SWEEP Management Committee.

ABSTRACT

The Effect of Time and Method of Control of a Red Clover Crop on the Growth and Yield of Corn

In 1987-90 seven trials were conducted in Middlesex and Huron Counties in southwestern Ontario to study the effect of time and method of control of a red clover cover crop on the growth and yield of corn. Drought conditions during late spring and summer in 1988-89 affected the performance of the cover crop and main (corn) crop. Excessively moist conditions in the spring of 1990 affected plant emergence and final plant stand especially on the spring tillage treatment.

Results from three years of study indicate that in general those treatments which included the use of a mechanical method for controlling red clover resulted in grain corn yields approximately 11% higher than those achieved with the average no-till treatments, although the effect was not always statistically significant. However, the amount of soil surface residue cover left after planting was unacceptable from an erosion control standpoint. The chemical kill treatments provided somewhat lower corn grain yield with excellent residue cover remaining after planting. The mechanical kill treatment using the chisel plough produced yields which were similar to the October chemical kill treatments and may be used as an alternative to using the moldboard plough.

The amount of dry matter collected from each of the treatment plots was related to the date and method of control of the red clover. The chemical treatment applied in May recorded the greatest amount of dry matter after planting followed by the April timing whereas the least amount (if any) was collected on the moldboard plough treatments.

Results of the rainfall simulation indicated that the mechanical kill treatments (moldboard and chisel plough) recorded significantly higher runoff volumes, soil losses as well as total phosphorus losses compared to either of the chemical kill treatments (October and April). The difference in the results obtained for the chemical kill treatments for the above parameters were not significant indicating that the time of the red clover kill did not affect the erosion control of these treatments. In addition, no significant differences between the chisel and moldboard plough treatments were reported for these parameters.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

EFFECTS OF TILLAGE ON THE QUALITY AND QUANTITY OF SURFACE AND SUBSURFACE DRAINAGE WATER: UPLANDS

FINAL REPORT

January, 1992

Prepared by:

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Guelph, Ontario

In cooperation with:

Don Lobb, Conservation Farmer, Clinton, Ontario;
Ontario Ministry of the Environment RAC Project # 913, Jim Eddy, Liaison Officer; and,
Partners in Nitrogen Project; Ontario Ministry of Agriculture and Food and The Fertilizer Institute of Ontario

Under the Direction of:

ECOLOGICAL SERVICES FOR PLANNING LIMITED,
Guelph, Ontario - Subprogram Manager For TED

On Behalf of:

AGRICULTURE CANADA
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Disclaimer:

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EXECUTIVE SUMMARY

A study was undertaken to determine the effects of tillage system on the quantity and quality of surface runoff and tile drainage water. Previous studies have suggested that the increased infiltration and occurrence of macropores in no-till systems may increase the risk of movement of chemicals to the groundwater. Thus, no-till systems may solve one problem (surface water quality), but create another problem (groundwater quality).

The study was carried out on the long term no-till - moldboard plough comparison established by Don Lobb, a conservation farmer near Clinton, Ontario. The soil at the site is a sandy loam. Three tile lines in each of the two tillage systems were instrumented for monitoring tile flow quantity and the concentrations of nitrate nitrogen and phosphorus.

Multi-level groundwater samplers were also installed in each treatment, and soil coring and the application of tracers (chloride) was used to track the movement of soluble chemicals. Detailed solute transport experiments under controlled application of water were also carried out to characterize the soil transport properties. The installation of equipment was started in the fall of 1988 and finished in spring of 1989. The site was planted with corn in 1989 and soybeans in 1990.

Surface runoff was monitored by installing runoff collection flumes on selected soil landscape positions within the study field. Rainfall simulation studies and characterizations of the hydraulic soil properties controlling surface runoff were also carried out in cooperation with other studies.

No significant tile flow was recorded until late fall 1989. From Oct. 1, 1989 to Oct. 1, 1990 a total of 121 cm of precipitation was recorded. Total tile flow amounted to approximately 19.0 cm with no significant differences between tillage systems. Movement of water below the tile line was significant and estimated at 49 cm of water.

No-till had significantly higher average concentration and water flux averaged concentration of NO_3-N in the early spring and fall periods compared to moldboard, but the reverse was true in the late fall. The average concentrations in both systems exceeded the drinking water quality limit of 10 mg NO_3-N/l. The average concentration was 10.7 mg NO_3-N/l in both systems.

Total nitrogen leaching from the 1989 corn crop was estimated at 80 kg N/ha and 50 kg N/ha in the no-till and conventional till systems respectively. The increased N leaching in the no-till was attributed to a higher N soil test in the no-till system and a requirement for less N fertilizer than the moldboard systems. Both systems had the same

fertilizer applied (160 kg N/ha). The amount of N lost by leaching in each replicated plot was significantly correlated to the difference between the fertilizer N applied and the fertilizer amount required according to the N soil test.

Detailed transport studies indicated more macropore transport in the moldboard plough system than the no-till system. However, the average solute transport velocity was faster in the no-till, which was attributed to increased occurrence of blocked pore domains.

The no-till system should not result in an increased risk of chemical contamination of our groundwater resource. If the nitrogen soil test is used to determine fertilizer requirements then the occurrence of over-application of N fertilizer should be significantly reduced in all tillage systems.

Surface water runoff from both the no-till and moldboard treatments was negligible at this site. This was attributed to the very high infiltration rates of the sand-loam soil. Runoff simulation indicated that increase water runoff would be expected in the no-till treatment for very large rainfall events. However, total phosphorus loss would be 2 to 4 times lower than the moldboard treatment.

Dissolved ortho-phosphorus and nitrate N in runoff water was also very low in the sandy-loam textured soil. However, runoff simulation on a clay-loam textured part of the field indicated that ortho-phosphorus in the runoff was significantly higher in the no-till compared to moldboard treatment. This, combined with an increased runoff volume from the no-till may be a problem in heavier textured soils.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

APPENDIX I - X
EFFECTS OF TILLAGE ON THE QUALITY AND QUANTITY OF SURFACE AND SUBSURFACE DRAINAGE WATER: UPLANDS

FINAL REPORT

January, 1992

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Under the Direction of:	ECOLOGICAL SERVICES FOR PLANNING LIMITED, Guelph, Ontario - Subprogram Manager For TED
On Behalf of:	AGRICULTURE CANADA RESEARCH STATION, HARROW, ONTARIO N0R 1G0
Disclaimer:	The views contained herein do not necessarily reflect the views of the Government of Canada or the SWEEP Management Committee.

Appendix I:	Pressure Transducer Cr21x Controlling Program and Temperature Calibration
Appendix II:	Detailed Theory, Equations, and Analysis Methods for using Time Domain Reflectometry to Measure Unsaturated Solute Transport Parameters
Appendix III:	Parameter Estimates of Field Solute Transport Models Based on TDR Measurements
Appendix IV:	Daily Meteorological Data
Appendix V:	Daily Tile Flow Measurements
Appendix VI:	Hourly and Daily Nitrate Nitrogen and Chloride Concentrations in the Tile Flow
Appendix VII:	Daily and Cumulative Nitrate Nitrogen and Chloride Loading From the Tile Lines
Appendix VIII:	Nitrate and Chloride Concentration Measurements From Multi-Level Groundwater Samplers
Appendix IX:	Nitrate and Chloride Concentrations in the Soil at Different Times
Appendix X:	Detailed TDR Readings for the Controlled Solute Transport Experiments

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

MANAGEMENT OF FARM FIELD VARIABILITY
I. QUANTIFICATION OF SOIL LOSS IN COMPLEX TOPOGRAPHY
II. SOIL EROSION PROCESSES ON SHOULDER SLOPE LANDSCAPE POSITIONS

FINAL REPORT

January, 1992

Prepared by:	Dr. R.G. Kachanoski, Dr. M.H. Miller, and D.A. Lobb, Principal Investigators DEPARTMENT OF LAND RESOURCE SCIENCE, CENTRE FOR SOIL AND WATER CONSERVATION, UNIVERSITY OF GUELPH, Guelph, Ontario
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Under the Direction of:	ECOLOGICAL SERVICES FOR PLANNING LIMITED, Guelph, Ontario - Subprogram Manager For TED
On Behalf of:	AGRICULTURE CANADA RESEARCH STATION, HARROW, ONTARIO N0R 1G0
Disclaimer:	The views contained herein do not necessarily reflect the views of the Government of Canada or the SWEEP Management Committee.

EXECUTIVE SUMMARY

This report documents the rational, objectives, and general methodology of the SWEEP/TED Management of Farm Field Variability Project. In addition, two specific aspects of that project are also documented.

In the first study the movement of soil in a complex three dimensional landscape typical of southern Ontario is examined using ^{137}Cs as a soil tracer. The study made use of a previous study by L.S. Crosson and R.D. Protz in the Department of Land Resource Science, University of Guelph. They sampled 180 soil landscape positions in a 10 m by 10 m grid in 1972 and stored the soil cores. The site was resampled in 1987 and through the SWEEP/TED program the soil samples were analyzed for ^{137}Cs. The ^{137}Cs in soil comes from atmospheric deposition (fall-out) from above ground nuclear testing in early 1950's and 1960's. The ^{137}Cs does not naturally occur in soil, but when added to soil it binds tightly and is not leached or taken up by plants to a significant extent. The ^{137}Cs deposited by the atmospheric deposition was subsequently mixed evenly in the plow layer by tillage. Thus, the movement (losses or gains) of ^{137}Cs in a landscape is caused by the movement of soil.

The ^{137}Cs landscape study indicated that soil loss on shoulder and crest slope landscape positions were greater than 100 t ha^{-1} yr^{-1}. This confirms earlier observations by L.A. Battiston and M.H. Miller, Department of Land Resource Science, University of Guelph, that these are areas of severe erosion. Total field scale soil loss was negligible with concave lower slope areas gaining all of the soil lost on the convex upper slope areas. The major conclusion is that water erosion is not likely the major process responsible for the soil loss. This suggests that the assumption that crop productivity losses from erosion and the environmental effects of erosion are linked, is not valid. Significant soil redistribution is occurring within the complex topography of Ontario, which is not related to the off field transport of sediment, phosphorus, and other chemicals.

In the second study summarized in this report, the processes

responsible for the severe erosion on upper slope landscape positions, specifically shoulder slopes, are investigated. The study was carried out as part of the M.Sc. thesis research of D.A. Lobb, Department Land Resource Science, University of Guelph. The hypothesis of which was that the soil being lost on these slope positions is the result of the mechanical action of tillage equipment.

Tillage erosion, the net downslope translocation of soil by tillage, was measured on eight shoulder slope landscape positions in two topographically complex field sites typical of the upland regions of southwestern Ontario. Cesium-137 was utilized as a labelling element to generate a tracer-pulse for the measurement of soil translocation. Soil translocation was calculated using the synthetic step response distribution synthesized from a succession of convoluted ^{137}Cs pulse response distributions. Paired plots were utilized to compare soil translocation by upslope and downslope tillage.

A single sequence of conventional tillage operations, consisting of fall moldboard plow, and spring tandem disc (double pass) and C-tine cultivator (single pass), translocated upslope approximately 80 kg of soil per meter slope width when tillage was conducted upslope, and translocated downslope 120 kg m^{-1} slope width when tillage was conducted downslope. Therefore, the net downslope soil translocation of two tillage sequences, one upslope and one downslope, was approximately 40 kg m^{-1} slope width. Assuming tillage operations are conducted upslope and downslope equally as often, the rate of net downslope soil translocation would be approximately 20 kg m^{-1} slope width per tillage sequence. Assuming one sequence of tillage operations occurs per year, the rate of net downslope soil translocation would be approximately 20 kg m^{-1} slope width per year. The convex slope length between the crest and the position of the plots was approximately 3 m. Assuming this distance was the source length for the net downslope soil translocation, 20 kg m^{-1} slope width per year represents the total annual soil loss from the 3 m slope length. The average annual soil loss over this convex slope length would be 6.7 kg m^{-2} yr^{-1}, or 67 t ha^{-1}

yr^{-1}, when tillage operations occur upslope equally as often as downslope. Tillage erosion is a major cause of the severe soil loss observed on shoulder slope landscape positions in the complex topography typical of the upland regions of southwestern Ontario.

The significance of the conclusion that soil loss by tillage translocation is an order of magnitude higher than soil loss by water cannot be overstated. The implications are discussed in detail in this report. Briefly, soil loss by tillage will be restricted to the upland regions of Ontario, but will occur to some degree on all convex slope positions in all regions with complex topography. The validity of all soil loss and erosion estimates using any form of soil tracer such as ^{137}Cs are questionable unless the changes are known throughout the landscape. Predictive soil loss and crop productivity models that do not include the process of soil loss by tillage will not represent reality for cultivated land in complex topography and will have little predictive value. Preventative and remedial managements which do not control tillage soil loss will have little value in maintaining or enhancing soil quality.

Recommendation are also discussed and include reducing the frequency and intensities of tillage. In addition, the size of tillage implements should be reduced. The possibility of varying tillage patterns within fields is also discussed. Further research, on the amount of tillage soil loss by secondary tillage implements and the amount of loss under different topographic shapes and equipment speeds needs to be carried out.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

REPORT ON "TYE-DRILL" MODIFICATIONS FOR SOWING SOYBEANS ON COMMERCIAL FARMS UNDER NO-TILL CONDITIONS

FINAL REPORT

January, 1992

Prepared by:	**SOUTHWESTERN ONTARIO AGRICULTURAL RESEARCH CORPORATION (SWOARC) Harrow, Ontario**
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On Behalf of:	**AGRICULTURE CANADA RESEARCH STATION, HARROW, ONTARIO N0R 1G0**
Disclaimer:	**The views contained herein do not necessarily reflect the views of the Government of Canada or the SWEEP Management Committee.**

Executive Summary

In 1988, a study was initiated by a group of farmers in the Rondeau Bay area of Kent County. The goal of the study was to determine if more aggressive and better matched coulter/presswheel combinations would improve the performance of the Tye drill for narrow row planting of soybeans in a no-till system. Experiments with the Tye drill in previous years had shown a tendency for poor seed establishment due to non-uniform seed depth, resulting in the exposure and desiccation of the seed.

In year one of the study, side by side comparisons of crop performance were made for fields planted with the Tye drill and with conventional planting units. The Tye drill was outfitted on one side with a bubble coulter and two V-presswheels with 8" rows, and on the other side with a fluted coulter and a single presswheel.

The results of the first year of research were inconclusive, due in part to the drought of 1988. While plant populations at two of the five sites were significantly higher on fields planted with the Tye drill compared to the conventional planter, the differences in yields were not significant.

The study continued in 1989 using the same comparisons as in Year 1, with some additional treatments. The Tye drill equipped with 1" fluted coulters across the front was outfitted on the left half portion of the drill rows with single presswheels while the other half had standard V-type (double) presswheels. On demand, a rake could be dropped behind the full width of the drill. It was

hoped that one of these combinations would provide a more favourable seedbed environment, which would translate into greater emergence and yields.

The results of the 1989 field season were not encouraging for any of the Tye drill treatments. At all of the sites, plants seeded with conventional planters experienced more rapid and vigorous emergence when compared to all other treatments. At all but one of the sites, the yield on the plot that was planted with the conventional planter was greater than any of the corresponding yields from the Tye drill treatments.

The results of two years of experiments with the Tye drill were not conclusive. The farmers who were involved in the study are still interested in making minor adjustments to the coulters of the Tye drill in an effort to improve the seed placement. They would also like to evaluate the performance of the Tye drill on a field scale. There was some feeling amongst the farmers involved in the research, that the plot scale research may have introduced errors and biased the results in favour of the planters.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

MANAGEMENT OF MULCH TILLAGE SYSTEMS ON CLAY SOILS

FINAL REPORT

March, 1992

Prepared by:	G.A. Stewart, Dr. T.J. Vyn, CROP SCIENCE DEPARTMENT, UNIVERSITY OF GUELPH, Guelph, Ontario
Under the Direction of:	ECOLOGICAL SERVICES FOR PLANNING LIMITED, Guelph, Ontario - Subprogram Manager For TED
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EXECUTIVE SUMMARY

Field experiments were conducted at Lucan (silt loam soil) and at Comber (clay loam soil) in 1991 to evaluate mulch tillage system effects on soil properties and corn growth and yield. At each location two experimemtal sites were established; one following a previous crop of grain corn and one following soybeans.

The aim of this study was to provide specific recommendations for various mulch tillage systems in regards to the effect of soil moisture content at the time of fall tillage and on the timing of spring secondary tillage within a mulch system. In addition, various tillage equipment was assesed for its impact on soil properties and corn growth following previous crops of corn and soybeans.

Measurements were taken on soil roughness, residue cover, soil moisture, aggregate size distribution, penetrometer resistance and corn growth and yield.

Soil physical properties and crop response were not affected by soil moisture contents at the time of fall tillage when the range between "wet" and "dry" conditions was 2-5% (gravimetric soil moisture). No particular mulch implement appeared to be less suited than others to working in wetter soil conditions.

Harrowing or levelling operations in the fall following chisel plowing and performing secondary tillage earlier in the spring may effectively reduce soil drying rates. However, those practices will probably have a noticeable impact on seedbed conditions only in springs where there are significant and prolonged early spring drying trends.

In general, mulch tillage systems were more suited to corn production in terms of soil conditions and corn yield when soybeans rather than corn was the previous crop. However, following soybeans, nearly all mulch tillage systems reduced residue cover to levels where significant protection from soil erosion will not be provided. Our recommendations based on this study would be to perform no fall tillage operations following soybeans and to limit tillage in the spring to a minimum.

Following corn, most mulch tillage operations provided adequate soil residue cover but, produce soil physical conditions (coarser seedbeds, greater soil strengths) inferior to those obtained by moldboard plowing. Generally this did not result in lower corn yields on the silt loam soil but on the clay loam soil mulch systems tended to result in corn yields lower than those obtained by moldboard tillage.

This study was conducted over a single season which included some extreme weather conditions and therefore caution should be exercised in drawing conclusions from this data.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

EVALUATION OF ROW CROP PLANTER MODIFICATIONS FOR CORN PRODUCTION WITHIN CONSERVATION TILLAGE SYSTEMS

FINAL REPORT

March, 1992

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EXECUTIVE SUMMARY

Field experiments were conducted in 1990 and 1991 on a silt loam soil at Elora and a loam soil at Woodstock to evaluate various row crop planter modifications for corn production. The study included a total of six location/years; three where the previous crop was grain corn and three where the previous crop had been winter wheat underseeded to red clover. Experimental treatments examined at each site included conventional tillage (spring moldboard plow and secondary tillage) plus a wide range of coulters and residue clearing devices mounted on the planter so as to prepare a seedbed without any prior tillage.

Soil measurements included surface residue cover, soil macroporosity, bulk density, soil moisture and penetrometer resistance. Corn crop response was determined by measuring emergence rates, early season dry matter production, days to 50% corn flowering and final grain yields.

Results indicated that when winter wheat + red clover was the previous crop residue removal from the row area was accomplished more effectively with devices specifically designed for this task (ie. disc furrowers, spoked wheels, etc.) than when coulters were used independently. Following grain corn, however, fluted coulters alone were efficient in removing residue from the row area.

Soil physical property measurements indicated that in the seedbed (depth: 2.5-7.5 cm) fluted coulters resulted in penetrometer resistances, macroporosities and bulk densities that were generally not different from those obtained by moldboard tillage. The strict use of residue clearing devices resulted in seedbed soil strengths and densities which were greater than those resulting from the use of fluted coulters and in some cases slot tillage.

Differences in planting depth variability were generally not significant, however, the addition of residue clearing devices did tend to result in more uniform seed placement

following wheat + red clover.

Early season corn dry matter accumulation generally resulted in higher values for the conventional tillage system compared to any other zero-tillage treatment. At some sites there was a trend for those zero- tillage systems which employed fluted coulters to result in greater dry matter accumulation than when residue clearing devices were used.

Differences in grain corn yields were only significant in one of the six site/years. Following winter wheat + red clover there appears to be a yield advantage for the use of fluted coulters over strict residue removal. In general, fairly wide ranging changes in planting techniques (ie. hand planting, modified zero tillage, moldboard) did not result in yield differences, perhaps due to generally above average growing conditions. Results, therefore, should be interpreted with some caution.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

REPORT ON DEVELOPMENT AND OPERATION OF THE CROSS-SLOT PLANTER

FINAL REPORT

March, 1992

Prepared by:	RONDEAU AGRICULTURAL CONSERVATION CORPORATION, Blenheim, Ontario
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Summary

Normal Openers used for planters produce a "V" or "U" shaped opening. The "V" shape is usually produced with a double or triple disc. The seed is dropped into the bottom of the "V". Some problems with germination can occur if the opening is not closed up or if the soil on the sides of the "V" are smeared and compacted.

Massey University (Palmerston North-New Zealand) began developing a cross-slot planter in 1969. The concept of this planter was to place the seed and fertilizer on either side of the coulter using wings which formed a cross slot under the soil surface. The soil was lightly compacted on the seed to give a micro climate suitable for good germination.

The concept of the cross slot planter being used for corn and soybeans for no-till planting in Ontario was first proposed in 1989. During the 1989-90 season a program was developed through SWEEP to evaluate the cross-slot planter as no-till planting system. The opener units had to be adapted to a corn planter system.

Due to some redesign of the wings in New Zealand, the seed placement units did not arrive until the winter of 1990-91. The planter was used to plant corn and soybeans during the 1991 season.

A White Air Planter was loaned to the project by the White-New Idea Company. The planter had to be reconfigured to accommodate the cross-slot openers. The seed was directed down the wing on one side of the coulter while liquid fertilizer was applied through the wing on the other side.

Where tillage has been reduced it has been necessary to zone tillage in planting operations to get a good micro climate for seed germination. The cross-slot planter has reduced or eliminated a number of these concerns. Hair pinning of residue in the seed slot has been eliminated. There is no need for tillage coulters and double disk openers which reduces equipment and power requirements.

The crusting around the seed has been eliminated and the smearing of moist soil has been reduced with the cross-slot planter. There is less disturbance of the soil around the seed zone thus, the mycorrhizal effect is maintained, thus speeding up germination and growth. The amount of testing in 1991 was limited. The results however, look good and a continuation of this program with expanded testing and evaluation would be encouraged for the 1992 growing season.

A SWEEP report authored by Dr. Murray Miller, Land Resource Science, University of Guelph is available ' Comparison of Planters and Fertilizer Application Systems for No-Till Corn' which gives research results on the effectiveness of the cross-slot planter.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

THE USE OF COVER CROPS FOR NUTRIENT CONSERVATION

FINAL REPORT

March, 1992

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EXECUTIVE SUMMARY

Field experiments were conducted in 1990 and 1991 on a sandy loam soil at Ayr and a loam soil at Woodstock to evaluate the effectiveness of cover crops for nutrient conservation. Three cover crops, oilseed radish, annual ryegrass and red clover were established in 1990 in or following harvest of barley and winter wheat to which 1/2, 1 and 2x the recommended rates of N had been applied. Attempts to establish cover crops in corn were largely unsuccessful. Cover crops were sampled periodically to determine biomass production and N and P uptake. Soil and soil solution samples were taken periodically in the fall of 1990 and spring of 1991 and analyzed for NH_4^+ and NO_3 nitrogen. Corn was grown on all plots in 1991 without N addition to evaluate the release of N from the cover crops.

The potential for contribution of N and P to surface runoff by leaching from cover crops during the winter and spring was evaluated in laboratory leaching studies using a rainfall simulator.

Cover crop dry biomass at Ayr ranged from about 1000 kg ha^{-1} for ryegrass to over 4000 kg ha^{-1} for red clover. Differences were much less at Woodstock with cover crop biomass ranging from slightly below 2000 to slightly above 3000 kg ha^{-1}. Oilseed radish biomass following wheat at Ayr increased with increasing rate of N applied to the wheat but there were no other biomass responses to N rate on the main crop.

Red clover generally had the greatest biomass N content (kg ha^{-1}) while ryegrass had the least due primarily to the lower biomass production. Except for oilseed radish following wheat at Ayr, biomass N content was independent of N rate applied to the barley or wheat.

Oilseed radish had a considerably greater P concentration and biomass P content (kg ha^{-1}) than either ryegrass or red clover.

Soil mineral N content (NH_4^+ and NO_3^-) in the upper 45 cm of soil was reduced by all cover crops compared to the check (no cover crop) in September. Mineral N contents decreased markedly at Woodstock by November even on the check plot. Mineral N contents of soil at Ayr did not change appreciably between the September and November samplings.

Concentrations of NO_3^--N in soil solution at the 75-cm depth were very low at Woodstock at all sampling times in the fall of 1990. This suggests that the decrease in soil mineral N content between September and November was most likely due to denitrification rather than leaching. At Ayr NO_3-N concentrations at 75-cm depth in September were below 10 mg L^{-1} under ryegrass and oilseed radish but were between 30 and 50 mg L^{-1} under red clover and the check. These latter values decreased to 2 mg L^{-1} by December indicating considerable leaching had occurred.

In April and May, NO_3-N contents of the soil profile were greater for oilseed radish than for other cover crops or the check, indicating that N was being released from this crop earlier than from ryegrass or red clover. In June, soil mineral N contents were much greater for red clover than other crops on the check. Mineral N contents on oilseed radish plots were only slightly greater than the check plot while those on ryegrass plots were lower than the check.

The mineral N contents in the soil were reflected in N contents of the 1991 corn crop in June and August which were greatest following red clover and least following ryegrass. Final grain yields reflected this greater N availability being greatest following red clover and least following ryegrass. These results indicate that N in oilseed radish is released earlier than desirable for use by the succeeding crop whereas ryegrass immobilizes N, with less being available than where no cover crop was grown. Release of N from red clover was closely related to the demands of the corn crop.

The laboratory rainfall simulation studies confirmed the ease of release of N from oilseed radish. A greater proportion (10-11%) of N in oilseed radish was removed during the leaching compared to 6-9% for ryegrass and 5-8% for red clover. In addition P concentrations in leachate from oilseed radish were much greater (10-14 mg L^{-1}) than for ryegrass (6-8 mg L^{-1}) or red clover (3-4 mg L^{-1}). Thus the potential for increased dissolved P in runoff from oilseed radish is much greater than for ryegrass or red clover.

The ideal cover crop, in terms of nutrient conservation, would be one which absorbs N rapidly in the fall, retains the N (and P) during winter and spring, then releases the N during the summer for use by the succeeding crop.

None of the three cover crops met all three of these criteria. Although oilseed radish absorbed N rapidly in the fall, it did not retain the N through the spring. In addition it increased the potential for dissolved P in spring runoff. Ryegrass appeared to absorb N and retain it through the winter and spring, but it did not release it rapidly enough for the succeeding crop. Red clover was very effective in retaining N through the winter and spring and in releasing it to the succeeding crop. There was, however, considerable leaching of NO_3-N from the red clover plot at Ayr.

All conclusions from this study must be interpreted with considerable caution because they are based on only a one-year study.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

COMPARISON OF PLANTERS AND FERTILIZER APPLICATION SYSTEMS FOR NO-TILL CORN

FINAL REPORT

March, 1992

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EXECUTIVE SUMMARY

A project was conducted in response to difficulties being encountered with conventional fertilizer placement systems for corn on no-till planters. To overcome these difficulties, farmers have made various modifications to planters and fertilizer application systems. This project evaluated three recent developments in fertilizer application systems: (1) a cross-slot planting system developed in New Zealand which results in less soil disturbance than other no-till planters and places fertilizer closer to the seed row than a conventional side band (5 cm to side and 5 cm below) (2) a strip-band fertilizer application system developed at Guelph which places fertilizer in two strips, one on either side of the row and about 2 cm below (3) a coulter-strip fertilizer application in which the fertilizer is deposited on the soil surface in front of a fluted coulter.

Experiments were conducted at two field sites in Huron Co. and Oxford Co. in 1990 and at three sites in 1991, one in each of Kent, Huron and Oxford Cos.

The specific objectives of the study were:

a) To compare the effectiveness of planting and fertilizer application using the cross-slot, strip-band and coulter-strip application systems.

b) To compare the cross-slot planter with a conventional planter under varying soil conditions.

At each site varying rates of fertilizer were applied based on the phosphorus required according to the OMAF soil test system. Plant samples were collected periodically during early growth stages to determine shoot growth and nutrient concentrations. Final yields were determined at maturity.

The strip band application did not increase early season dry matter or shoot P concentration compared to the side band. Final grain yields were somewhat greater at both sites in 1991 although the differences were not significant at $P=0.05$. A similar result was obtained in a previous study conducted in 1989. When the results of the two years were combined, the mean difference (380 kg ha^{-1}) was significant at $P=0.08$. There was no response to phosphorus at either site in 1990 so a comparison of application methods was not meaningful. It is concluded that the strip band is marginally superior to the

side band but the difference is not sufficient to justify the planter modifications required. Yield increases of a similar magnitude can be obtained by applying a small amount of fertilizer with the seed.

The coulter-strip fertilizer application system did not result in significant differences in early shoot growth or nutrient concentration compared to the side band using the same planter for both placements. Similarly there was no difference in grain yield. However, the experiments did not allow a good comparison of the coulter-strip system. In 1990 there was no response to fertilizer P so a comparison of placements is not meaningful. In 1991 the conditions for planting were not good so there was essentially no mixing of the fertilizer with the soil with the coulter strip system. The location and distribution of P determined in 1990 did indicate that the fertilizer was mixed only with the upper 2-3 cm of soil. This would not be expected to provide phosphorus to plants in the early growth stages.

The cross-slot planter resulted in yields comparable to the Guelph planter. This was our first experience with this system and there were some aspects that could perhaps be improved. We are not confident that we were obtaining the desired fertilizer application rate. Also, increasing the weight on the planting units may be necessary to achieve proper penetration under some conditions. We believe that the cross-slot planter has potential advantages and should be investigated further.

In addition to comparison of planters and fertilizer placement, this study permitted an assessment of the adequacy of the phosphorus fertilizer recommendations for no-till corn based on the OMAF soil test. There were seven field experiments over three years in which fertilizer rates ranging from 1/2 to 4 x the recommended rate were applied as a side band with the Guelph planter. At none of the seven sites was there any response to fertilizer P application in excess of that recommended. Averaged over all seven sites, the recommended rate was the most profitable. At most sites, the soil test was low resulting in a recommended rate of 50 kg P_2O_5 ha^{-1} or greater. In 1990, when the recommended rates was lower, there was no response to fertilizer P. These data indicate that, even with low available P values, current recommendations are adequate.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

MANAGEMENT OF FARM FIELD VARIABILITY

III. EFFECT OF TILLAGE SYSTEMS ON SOIL AND PHOSPHORUS LOSS

FINAL REPORT

January, 1992

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EXECUTIVE SUMMARY

This report is the second of three reports from the SWEEP/TED project "Management of Farm Field Variability". The first report documented the rational, objectives, and general methodology of the project. In addition, it summarized the work on the quantification of soil loss in a complex three dimensional landscape in southern Ontario, and the influence of tillage translocation as a process responsible for the severe soil loss on shoulder/crest slope landscape positions.

The objective of this part of the project was to measure soil and phosphorus losses on various soil landscapes, under different tillage systems. A subset of benchmark locations (soil landscape positions) were selected from the provincial Tillage-2000 research/demonstration project. A total of approximately 400 different benchmarks were selected.

At each of the benchmarks the amount of ^{137}Cs, a soil tracer, was measured in the fall of 1987 and again in 1990. The ^{137}Cs in the soil came from atmospheric thermonuclear testing in the early 1950's and 1960's. The cesium was dispersed into the upper stratosphere around the world, and was subsequently deposited in the soil by precipitation. The cesium binds to the soil and will not move unless the soil it is bound to, also moves.

The measurements at each sample date and location involved taking 9 soil cores (3 m by 3 m grid) for estimation of plow layer depth and two samples for bulk density and to obtain the soil sample for subsequent cesium analysis. The ^{137}Cs was analyzed by high efficiency Gamma Spectroscopy methods. The soil was also used for measurement of total phosphorus. The purpose of the measurements was to use the change in ^{137}Cs between measurements, to give net soil losses. The soil losses could then be combined with the phosphorus measurements to give phosphorus losses in the various soil landscapes.

The method of estimating soil loss from ^{137}Cs is well known and used throughout the world. However, the method assumes that a relationship exists between the loss of cesium at a particular site and the amount of net soil loss. For water and wind erosion there is usually little deposition on upper, and mid-slope positions. Thus, cesium and soil loss should be related. However, as the previous report of this project has shown (from D.A. Lobb, M.Sc. Thesis, Dept. of Land Resource Science, University of Guelph), tillage translocation of soil is a major process redistributing soil in complex topography. This process results in significant lateral mixing of soil/cesium. The net effect is that cesium loss at a particular soil landscape is not necessarily related to soil loss. Thus, in the absence of a good mechanistic model or understanding of tillage translocation, only a full mass balance of cesium in the landscape can be used to estimate soil loss.

Unfortunately, the Tillage-2000 benchmarks were not established to monitor the full three dimensional landscape. Only a cross-section of the landscape was used. This is an efficient methodology to examine landscape effects on yield, water erosion, soil properties, under different tillage systems, but not for a full mass balance of cesium.

The moldboard tillage system resulted in considerably more change in ^{137}Cs (1987 to 1990) than either minimum or no-till systems. Average soil losses across all Tillage-2000 field sites were 60.0, 30.0, and 0.0 t ha^{-1} yr^{-1} for the moldboard, minimum, and no-till systems respectively. Estimated phosphorus losses were 40.0, 20.0, and 0.0 kg P ha^{-1} yr^{-1} for the same tillage systems respectively. The minimum-till average loss values are not a good indication because most of the loss occurred on two sites. For 9 out of the 11 minimum-till sites soil and phosphorus loss was negligible. On one minimum-till site the loss was excessive which probably is the result of poor mass balance rather than an actual loss. These estimated losses are based on the assumption that the average ^{137}Cs loss from the benchmarks is representative of the mass balance of the entire field.

Paired tillage comparisons gave similar trends in the soil and phosphorus loss estimates. Annual losses of phosphorus were on average 48.0 and 35.0 kg P ha^{-1} for the five paired moldboard versus minimum-tillage field sites respectively, and 20.0 and 4.0 kg P ha^{-1} for the paired moldboard and no-till sites respectively. The differences in the losses in the moldboard sites paired to either minimum or no-till treatments reflects differences in soil types and probably tillage intensity. The paired minimum and no-till sites had negligible losses. These sites (i.e. where minimum-till tends to be the conventional system) are lighter textured and in general are tilled less intensively than the minimum-till sites paired with the moldboard system. Thus, the data seem consistent with what is known about the influence of tillage on soil and phosphorus losses. However, it must once again be stated that the loss estimates may not represent off-field losses related to water runoff. This, however, is a scale problem regardless of the within field processes (tillage translocation or water redistribution) which can only be answered with a true three dimensional mass balance.

Average ^{137}Cs losses from specific landscape positions were quite variable, with large losses generally observed on shoulder/crest slope landscape positions. Soil losses from these landscape positions were very large, in many cases exceeding 100 t ha^{-1} yr^{-1}. The variable nature of the losses (or gains) is consistent with the study by Battiston et al. (1987) and the previous report from this project suggesting that tillage translocation is a dominant process responsible for soil redistribution within a field.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

MANAGEMENT OF FARM FIELD VARIABILITY
IV. CROP YIELD, TILLAGE SYSTEM, AND SOIL LANDFORM RELATIONSHIPS

FINAL REPORT

May, 1992

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EXECUTIVE SUMMARY

This report documents the last two objectives of the SWEEP/TED project "Management of Farm Field Variability". The objectives of this part of the project were to determine crop yield response to different tillage systems, at different landscape positions, and relate the variations in crop yield response to soil and landform properties. The possibility of implementing variable management was examined by quantifying the stability of the yield response pattern over a number of years.

The study was carried out in cooperation with the provincial Tillage-2000 project, which is a cooperative project of the Ontario Ministry of Agriculture and Food (OMAF), the Dept. of Land Resource Science (Univ. of Guelph), and cooperating farmers. Details of the study are given in the annual reports of the project, which are available from OMAF.

Field sites were selected from the existing Tillage-2000 sites for detailed examination of the relationships between landform, soil properties, soil loss, tillage management, and crop yield. At each field site, two tillage systems (conventional, conservation) had been established and permanent benchmark monitoring locations selected. The conservation system was defined as any tillage system which should decrease the loss of soil from the field by erosion. The tillage system were classified as no-till if no primary or secondary tillage was completed, minimum till systems if no inversion tillage (moldboard plough) system was used and moldboard if a moldboard plough was used to invert the soil.

Landform at each benchmark was characterised by carrying out a detailed elevation survey using a laser theodolite, and calculating parameters based on a digital elevation model and classification system. The landform classification is based on the slope gradient and change in slope gradient with distance (curvature) at a location. A concave surface with low slope is classified as a footslope, while a convex surface with low slope is a crest/shoulder position. In addition the cross-slope curvature can be causing water to converge (concave cross-slope) or diverge (convex cross-slope) at a point and landforms are further divided by this classification.

Relative soil loss was obtained from relative changes in ^{137}Cs content (a naturally occurring soil tracer) measurements. Soil properties were obtained from a 1.0 m soil core taken at each site using a hydraulic soil sampler. Yield measurements collected as part of the Tillage-2000 program were entered into the data base containing all of the other information. Soil sampling for soil fertility analysis was also completed. Indices for plant available water and air filled porosity were calculated from soil profile data. The objective of the sampling program was to obtain as complete a database as possible. A copy of the database accompanies this report.

The 5 year (1986-1990) average grain corn, soybean, and small grain yields in the paired conservation and conventional tillage systems were not significantly different. In addition, field by field, and year to year differences in yield were equally variable in the conservation and conventional systems. The paired moldboard and minimum tillage sites suggested a slight yield advantage to the moldboard system. Average relative crop yields across all crop types were higher in the moldboard system for all years except 1988. A total of 23 out 36 plot years had higher yields on the moldboard system compared to the minimum tillage system.

The paired no-till and moldboard tillage sites indicated no significant difference in yield for any of the crop types. A total of 14 out of 23 plot years had a higher yield in the no-till system than in the moldboard system. Average relative yield across all crops was higher in 1987 and 1988 in the no-till compared to moldboard, but lower in the other three years.

The paired no-till and minimum tillage sites indicated a slight yield advantage to the no-till system. The average no-till yield was significantly higher than minimum tillage yield (0.1 probability for both the soybeans and small grain crops.

Conservation tillage systems, both overall and in the paired tillage comparisons, did relatively better than conventional systems in 1988 (a drought stress year) than in any other year. This suggests that conservation tillage systems are more buffered against adverse crop growth conditions than conventional systems.

Soil texture (Ap horizon) class and tillage X texture class interactions were significant (0.001 probability) in explaining the variations in yield of all crop types. Landform class was significant for corn and soybeans, but not small grains. A regression of the ratio of no-till yield/conventional tillage yield against %sand content of the Ap horizon was significant (0.05 probability). The regression indicated that for %sand contents greater than 36 % the no-till yield would on average be higher than the conventional tillage system. The no-till yield for finer textured soils would on average be lower than conventional tillage systems. The interaction of tillage and texture is suggested as the reason for little overall differences in tillage system on crop yield, across all farm sites.

Landform classification criteria as proposed by Pennock and de Jong (1987) are not sensitive enough at the elevation measurement scale used in this study (i.e. 10 m grid). The criteria for backslope versus level class (6.5 % slope) resulted in an unacceptably large number of level class designations. The criteria was changed to 3 % slope gradient.

A general analysis of covariance confirmed the presence of significant covariance between the major soil properties. The 7 unit landform classification system was not very useful in explaining variations in soil properties. This was partly attributed to the high variability of texture within the landform classes, and the covariance of texture and other soil properties.

A sub-classification by upper, middle, and lower slope position within each of the original landform classes explained a significant (0.05 probability) amount of the variability of almost all soil properties, especially those related to soil loss. The conceptual model of the slope location of the original landform classes was correct for approximately 60-70 % of the benchmarks. However, a significant number of benchmarks were found at slope positions not conforming to the conceptual model. The poor success of the original 7 landform classes in explaining the spatial variations of soil properties was attributed to the conflicting patterns that water flow and tillage translocation would have on soil properties.

Solum depth was significantly related to soil texture class, but ^{137}Cs content was not related to texture. This suggests that the amount of soil loss is not related to texture, and the increased solum depths in the sandy soils are related to pedogenic processes. The independence of soil loss on soil texture, and the higher cesium loss on upper slope compared to middle slope positions are contrary to water erosion theory, but consistent with tillage translocation theory.

The difference between the highest and lowest yielding areas in a field, across all years and all sites was 40 % of the mean field yield. Tillage system did not significantly affect the within field variations in yields. The lowest, highest, and range, of relative yield difference were similar in the paired tillage comparisons. The standard deviation of relative yield difference was slightly higher (0.05 probability) in the minimum compared to no-till system.

The percentage of within field variation of yield remained constant from year to year was on average 52 % and 56 % (significantly different at 0.10 probability), for the conventional and conservation tillage systems respectively. Approximately 3 % of the benchmarks had an average yield which was at least 30 % less than the average field yield. Another 5 % of the benchmarks were between 20 % and 30 % lower than the field average yield. A total of 15 %, and 4 % of the benchmarks had an average yield which was greater than 10 %, and greater than 20 % of the field average yield respectively. The relative ranking of the benchmarks with respect to relative yield was independent of the measurement year, but the year did affect the magnitude in all yield classes. The drought stress year (1988) resulted in much greater relative within field variations of crop yield.

A paired benchmark analysis on crop response on stress (low yielding) and non-stress (high yielding) benchmarks, in stress and non-stress growing conditions was carried out. It indicated that conservation tillage systems may be more buffered against adverse climatic growing conditions than conventional tillage systems. High yielding areas under conservation tillage dropped only 13.8 % in yield during a stress year, compared to 16.5 % decrease in the conventional system. Low yielding areas in the conservation system decreased 24 % in yield in the stress year, compared to a 31.1 % decrease in the conventional system. This benchmark data supported the paired field yield data, which indicated that the ratio of conservation yield/conventional yield was the highest in 1988 the drought stress year.

The 7 unit landform classification explained a significant amount of the within field benchmark yield data. Converging landforms had on average 8.5 %, 7.8 %, and 5.5 % higher yields of corn, soybeans, and small grains respectively, compared to diverging landforms. Across all crop types the average difference between converging and diverging landforms was 7.3 % (significant at 0.05 probability level). The diverging shoulder and backslope position had significantly lower corn and soybean yields, than the other landform units.

There was a significant interaction of soil texture class and soil loss, on relative crop yield losses. Benchmarks were separated on the basis of %sand in the Ap horizon and yield response correlated against cesium content in each texture class. Yield response to soil loss was predicted from these correlations. Severely eroded soils with a % sand content greater than 70 % had an average predicted yield loss of 37 % of the field average yield. The same severely eroded soils had a predicted yield loss of only 8.0 %, 4.7 %, and 0.7 % for Ap horizons with 50-70 %, 40-50 %, and 30-40 % sand content. The yield loss in all texture groupings increased during the 1988 growing season indicating soil loss was affecting available water, but more so in the sandier soils. The available water index of McBride and Mackintosh (1984) was significantly related to cesium content in the >70 % sand content group, but not in the other groups. The benchmarks with 20-30 %, and <20 % sand content had a predicted relative yield decrease of 4.3 % and 8.0 % respectively. Thus, the benchmarks in the medium texture classes had much less predicted yield loss from soil loss, than benchmarks with lighter or finer soil textures. This is consistent with the higher available water holding capabilities of medium textured soils compared to other textures.

The data in this project, and in the Tillage-2000 project indicate that it should be possible to implement a conservation tillage system with no loss in yield productivity. This is especially true for sandy textured soils where increases in yield are likely under conservation tillage.

For the range in soil and landform conditions in this report, there seems to be little benefit to adopting a minimum tillage system. No-till yields were equal or better than minimum till and the minimum till was slightly lower yielding than the moldboard tillage. In addition, the work on tillage translocation suggests that secondary tillage, which can sometimes be more intensive under minimum tillage, can result in significant soil loss off of shoulder/crest slope positions. The criteria of 20 % or 30 % residue cover to control water erosion is meaningless with regards to tillage translocation. Thus, unless a management procedure can be devised to control tillage translocation, minimum tillage can not be viewed as a viable alternative to a moldboard system in a sustainable production system. The minimum till system may control water and soil loss by water erosion, but it will not be stopping the decline in soil quality and crop productivity in the upland regions.

The study indicates that the sandy soils (>70 % sand) are the most fragile of all of the soil types. Soil loss in upper convex slope positions has already resulted in yield losses of 30-40 % of the average field yield. The productivity losses are even more severe in years of climatic stress. However, since on average these soils had a higher yield in no-till than in any other tillage system, there seems little reason for farmers not to adopt the no-till system immediately. The main mechanism of soil loss is tillage translocation, and water erosion is likely to be minimal considering the high infiltration capacities of sandy soils.

Conservation tillage systems appear to be increasing the soils buffering capacity against adverse climatic conditions, particularly drought stress. This is encouraging considering the possibility of increased frequencies of drought stress due to global warming trends. The full extent of the remediating capabilities of no-till is not very well understood and should be the subject of future studies. The remediation may appear to be faster than expected because the massive soil loss from tillage translocation has been stopped in the no-till, but continued in the conventional tillage system. Thus, even if the yield productivity of severely degraded areas is stabilized, it would appear that they have undergone an increase because of the continued decline in productivity of the conventional system. The actual rate of remediation, and degree to which it is possible to remediate these areas is unknown, and beyond the scope of this study.

A considerable amount of research activity is currently underway regarding variable management. A symposium on this subject will be held at the annual American Society of Agronomy meeting. Other symposia have been held the past few years by the American Society of Agricultural Engineers (ASAE). Most of the activity has centered on development of spatial location sensors, and variable application technology. There seems to be little doubt that the technical ability to vary management within the field will be present, the important missing link is the knowledge base to decide what kind of management should be done at each point in the field. The yield data indicates that reasonably consistent pattern of yield are present year after year. Thus, variable management from a cost benefit point of view is necessary. Technology for automatic measurement and recording of yield patterns is available, but more accurate equipment is needed.

The consistent yield differences in the benchmarks from year to year is encouraging, and it is clear that many of the differences are related to soil loss or the effects of soil loss. The sites with very large yield losses are diverging shoulder slope/crest positions as indicated by Battiston et al. (1987). This problem can be attributed almost entirely to tillage translocation. The obvious solution is not to till the fields. However, it may be possible to change the pattern of tillage. The necessity of at least alternating the direction of all tillage, including secondary tillage cannot be overstated. The net soil losses from alternating tillage directions is still very large, but much smaller than the loss from a single direction.

Without an accurate method of predicting the soil redistribution from tillage translocation, there does not appear to be much hope in explaining any more than about 40-50 % of the spatial variations of soil properties. The same constraint exists for predicting variations in yield response using only landform classification. The alternative is to measure and map yield response directly from year to year and identify sensitive areas from changes in yield from year to year especially during climatic stress conditions. While it is possible to predict that the areas of high yield loss will likely be the shoulder slope positions, it is not true that all shoulder slope positions have been eroded and thus will have yield reductions.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

EFFECT OF WOODLOT BORDERS AND CROP RESIDUE ON THE DISTRIBUTION OF INVERTEBRATES IN AGROECOSYSTEMS

FINAL REPORT

May, 1992

Prepared by:	P. Neave, DEPARTMENT OF ZOOLOGY, UNIVERSITY OF GUELPH, Guelph, Ontario
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On Behalf of:	AGRICULTURE CANADA RESEARCH STATION, HARROW, ONTARIO N0R 1G0
Disclaimer:	The views contained herein do not necessarily reflect the views of the Government of Canada or the SWEEP Management Committee.

Executive Summary

EFFECT OF WOODLOT BORDERS AND CROP RESIDUE ON THE DISTRIBUTION OF INVERTEBRATES IN AGROECOSYSTEMS

Peter R. Neave
University of Guelph

This study examined the relationships among distance from woodlots in agricultural fields, crop residue, and the abundance and diversity of soil invertebrates. Two sites were used in Southern Ontario. Each site had one field with crop residue over the winter of 1990, and one field without crop residue. Populations of cryptozoic (soil surface) fauna, foliage fauna, and earthworms were measured.

The abundance and richness of cryptozoic invertebrates declined significantly with increasing distance into the fields. The decline in abundance was dependent on date, the greatest decline with increasing distance into the field was in late fall. These declines suggest that cryptozoic invertebrates were present at distances further out into the field, despite their comprising few taxa, and that many of the invertebrates are dependent on the woodlots for winter shelter. Crop residue on the field over winter significantly increased cryptozoic abundance and richness at all distances from the woodlot in some fields, suggesting that crop residue promoted invertebrate persistence in these fields.

The numbers and richness of Carabidae (carabid beetles) increased significantly with increasing distance into the fields in late July and

August, particularly in the corn cropping systems. The crop residue appeared to have little effect on carabid distribution.

Eveness of the cryptozoic community increased significantly with increasing distance into the fields. Species dominance, therefore appears greater in the woodlot than in the field. Crop residue cover on some fields significantly decreased eveness at all distances from the woodlot.

Earthworm number and mass increased significantly with increasing distance into the fields, possibly because of increased competition from other macro-decomposers which were more abundant near the woodlot.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

THE FEASIBILITY OF BAND SPRAY APPLICATION IN CONJUNCTION WITH INTER-ROW CULTIVATION IN NO-TILL CORN

FINAL REPORT

May, 1992

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Executive Summary

The goal of this study was to develop an integrated weed management program for use in reduced-tillage corn production utilizing band herbicide application in conjunction with inter-row cultivation. Also it was our intent to further evaluate the efficacy and usefulness of specific preemergent and postemergent herbicide treatments suitable for use within this systems approach to weed management, and finally to test this technology under grower conditions using field scale equipment and large research plots.

The results of this study show that shallow cultivation between crop rows is very affective in providing control of weeds in these areas. Cultivation alone did not have a significant effect on crop yield. When cultivation was used, the low recommended herbicide rate provided equivalent weed control and yield to the higher recommended rate of herbicide, both when the herbicides were broadcast overall and when they were applied in a band over the row. These results show that one inter-row cultivation was satisfactory.

Most preemergent and postemergent herbicide treatments tested performed very well. Of the thirty treatments evaluated, only two treatments failed to provide consistent commercially acceptable weed control. Those two treatments could only be faulted one year out of three years of testing.

The large scale field trial was the ultimate test of the technology. Results show that crop yield was virtually unaffected by cultivation. Weed control was maintained at a high level, well above commercially acceptable standards, and the technology was easily adapted to large scale field operations. Soil disturbance was minimal, crop residue remained on the soil surface and the shallow layer of disturbed soil did not erode.

The farmer involved, and project manager, was quick to point out that the combine at harvest in damp conditions may tend to slide out of the undisturbed row area, particularly on side hills; in stoney conditions the cultivator may roll stones into the row area; and that root pruning could be a problem if the operator allowed the cultivator to penetrate too deeply. Also he noted that herbicide usage was reduced by 60% and weed management costs were reduced by 40% when this technology was applied to his general farming operation.

Growers can apply this concept immediately if they wish. All they need is the appropriate equipment. The herbicide treatments are currently registered for use.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

LAND RESHAPING OF LOWLAND CLAY SOILS

I. FIELD STUDY

FINAL REPORT

May, 1992

Prepared by:	CAN-AG ENTERPRISES, Guelph, Ontario
Under the Direction of:	ECOLOGICAL SERVICES FOR PLANNING LIMITED, Guelph, Ontario - Subprogram Manager For TED
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EXECUTIVE SUMMARY

Land planing is a procedure to alter the field topography, producing a uniform slope thus improving surface drainage. Using laser technology for elevation mapping, in conjunction with computer software programs, a design plan is created outlining topsoil cut and fill depths and locations. An earth scraper with a cutting bar controlled by a laser elevation beam is then pulled across the field to produce the desired design.

Water management techniques such as the innovative approach with land planning however, must be closely examined to determine the sediment and phosphorus losses associated with the surface runoff. In the fall of 1988 Can-Ag Enterprises was awarded a contract to design and construct monitoring stations, then record and sample runoff at these stations.

The goal of this study is to determine the efficacy, costs and farm management changes associated with land reshaping, in comparison to conventional water management practices.

The study involved four farms, located in Essex and Kent counties, each with a planed and an unplaned field. Sites 2, 3, and 4 had a monitoring station at the primary surface outflow location on each field. The fields at site 1 were divided into sections, each section having a drainage furrow leading to a rock chute and therefore enabling three monitoring stations to be established on each field. The stations consisted of a V-notch weir, a stillwell with a Richards type flow meter, and later Isco automated samplers (two placed at sites 1 , 2 and 3). Throughout the study, runoff volumes were logged, samples were collected, soils were evaluated and agronomic practices and responses were recorded. Analysis for total phosphorus and dissolved molybdate reactive phosphorus were performed in the Land Resource Science Department at the University of Guelph. The sediment content was determined at the Harrow Research Station where the samples were filtered before being sent to Guelph.

Results of the soil investigations indicated a lack of impact, with regard to soil quality, from planing. At all sites, topsoils were not completely removed in any locations though in a few places there was evidence of topsoil removal or addition. The assigned soil compaction ratings were similar for both the planed and unplaned field.

The results of the flow data indicated that increased runoff (L/ha) was associated with the planed field at two of the three well documented sites. Only at one site though, was the increased runoff (L/ha) on the planed field significantly greater than the unplaned field. Contrasting results were found at another site where the unplaned field contributed more runoff (L/ha) than the planed field. The fourth site had too few recorded events to be statistically analyzed.

The contrasting results between sites may be attributed to differences in the natural drainage patterns and differences in the sizes of the drainage basins. In the first year at site 2 though, we were able to construct basins of equal area on the planed and unplaned field using tomato beds. All the event occurrences with the equal area basins produced far more runoff (L/ha) from the planed field compared to the unplaned field. However there could be situations, such as at site 1, where dividing up the natural basins into smaller sections through planing would reduce the overall runoff.

The erosion characteristics of the two water management systems with regard to phosphorus and sediment losses through surface runoff are still not clearly defined. No consistent trends were observed or statistically determined, which might indicate that the phosphorus and sediment contributions to the runoff are event specific.

Differences between planed and unplaned fields appear when the sediment and phosphorus loadings are calculated with regard to total flow volumes. Sediment and phosphorus losses increased as runoff volumes increased. The planed fields on two out of the three well documented sites produced more runoff and therefore may contribute more phosphorus and sediment to the drainage channels. Obviously the key to reducing phosphorus and sediment loadings is to reduce runoff volumes. Determining the natural basins and drainage patterns within a field is the first step to choosing an appropriate water management system. Creating smaller basins through planing may reduce overall runoff (L/ha) if the natural topography is prone to extensive surface runoff into adjacent waterways. However, the situation may be reversed if the natural depressions hold back the surface runoff. Eliminating these depressions through land planing will increase the surface runoff. Therefore in this circumstance farmers wishing to reduce field surface water should consider alternatives to land planing.

The interaction of total phosphorus, dissolved reactive phosphorus and sediment appear to be event specific, depending on rainfall intensity, soil conditions, antecedent moisture, ground cover, etc.

Differences in runoff and losses from the planed and unplaned field did not show up with respect to agronomic practices and the resultant residue cover. Combining the data from the planed and unplaned fields indicated that an established crop providing ground cover during the growing season significantly reduced the phosphorus and sediment loss to the surface runoff.

The costs of land planing are high, estimated between \$260/ha and \$790/hectare, yet increased yields (when compared to unplaned fields) may only be achieved in wet seasons. Other benefits reported by the farmers include: earlier spring start; elimination of hard spots (ponding areas); consistent crop growth; and harvesting at the opportune time. These benefits and the periodic yield advantages however, may only justify the initial costs of the land planing procedure when lucrative cash crops (i.e. tomatoes) are grown.

The modelling component of the study provides a prediction of whether or not a runoff event will occur but further modification to the model is necessary to produce accurate assessments of runoff volumes and phosphorus loss. As well further modification is needed to allow more agronomic input.

Several recommendations were made upon completion of the study. For fields already planed, these include:

- a reduction of drainage basin size (area with 1 outlet) to a range of two to five hectares (depending on field size).
- construction of proper grass waterways and outlet points to reduce field edge erosion and trap sediment runoff.

For farmers who have not planed but require water management techniques, we recommend:

- observe natural drainage patterns in the field
- consider costs and environmental impact of each system
- areas with high runoff volumes to adjacent waterways may experience a reduction in runoff if planed
- fields with isolated ponding areas will experience an increase in runoff if planed and therefore alternatives should be sought
- standpipe surface inlets and sediment traps are a cost effective alternative to the planing procedure.

For researchers, we recommend:

- small basin monitoring provides necessary data for field scale erosion research.
- control structures should be more permanent in nature and if economically feasible use data loggers to record flows.
- field scale monitoring should continue, to provide accurate model calibration data.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

LAND RESHAPING OF LOWLAND CLAY SOILS

II. MODELLING REPORT

FINAL REPORT

May, 1992

Prepared by:	Andrew H. Marshall in association with CAN-AG ENTERPRISES, Guelph, Ontario
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Disclaimer:	The views contained herein do not necessarily reflect the views of the Government of Canada or the SWEEP Management Committee.

EXECUTIVE SUMMARY

The land planing studies, which were carried out by Can-Ag Enterprises Limited, were mathematically modelled using a modified version of the Chemicals, Runoff and Erosion from Agricultural Management Systems (CREAMS, Ver. 1.7) model. This modelling assignment focused on the first phase of model application, the prediction of overland flow episodes, and was based on a procedure which encompassed five areas of model development and application. These areas included problem identification, stated objective, development of method, results and evaluation of results.

Based on this procedure, 116 out of 130 observed episodes of overland flow were predicted for the twelve fields in the land planing studies for the time period from April'89 to September'90. In addition, 38 predictions were made which could not be explained, i.e. the failure of monitoring equipment. These results were dependent on a number of factors including the proximity of an agricultural field to precipitation measurement as well as the seasonal variation in infiltration characteristics of heavy clay soils.

The predictions of overland flow episodes resulted from a novel approach of applying the CREAMS Ver. 1.7 model to agricultural fields across seasons. This approach provided a solid basis for the next phase of modelling application: an emphasis on the prediction of flow quantities and sediment and phosphorus concentrations and loadings. The framework for such an emphasis could easily be patterned on the framework developed in this assignment, the first phase of model application.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

EVALUATION OF O.B.A.T.A. APPROACH TO LOW INPUT FARMING

FINAL REPORT

May, 1992

Prepared by:	CAN-AG ENTERPRISES, Guelph, Ontario
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EXECUTIVE SUMMARY

Many farmers are seeking alternatives that lessen their dependence on off-farm inputs (especially fertilizers and pesticides) that build soil quality, and that create a healthier environment. This report presents a three year evaluation of the excellent accomplishments of a small group of innovative farmers known as the Ontario Biological Aeration Tillage Association (O.B.A.T.A.). Their quest is to adapt low input farming methods on their farms and to extend promising alternatives to their communities.

The basic components of the O.B.A.T.A. approach are mechanical, biological and reduced chemical inputs. Important sub-components of each of these are summarized as follows. Mechanical tillage implements; a subsoiler used for pre-emergence or post-emergence soil aeration; and other farming implements for spraying, seeding, tillage, etc. The biological component entails kelp, sugar (eg. molasses) and fertilizer; cover crops; crop rotation; and reduced tillage. Reduced rates of herbicides and fertilizers are applied.

The purpose of this project was to evaluate these production practices; the next step is to use the favourable recommendations for extension purposes. The evaluation examines systems approaches to farming. A standard approach, the farmers' routine practice, is compared to the O.B.A.T.A. approach. These both vary considerably from farm to farm in terms of crops grown, availability of manure, and rotation of principal crops. One farmer adopted O.B.A.T.A. methods throughout his farm, so on his land different O.B.A.T.A. practices (comparison of cover crops, different fertilizer applications, tillage practices and manure applications) were examined.

The study was conducted on seven farms distributed across Oxford, Elgin, Haldimand-Norfolk and Waterloo Counties, spanning variable soil and climatic conditions. There were three complete years of results for two fields and several treatments within each field on Mint Klynstra, Jim House and Arpad Pasztor's farms. Various O.B.A.T.A. treatments were tested on John Van

Dorp's farm. Joe Gerber, Dave McIntosh and Dean Glenney were unable to participate during the entire period for various personal reasons.

The significant results of the monitoring program are summarized as follows:

Soils

- Soil fertility monitoring (P, K, Mg, Ca, pH and organic matter) revealed a lack of significant differences between the standard and O.B.A.T.A. management treatments. Comparisons were made for each year and between years for each treatment.
- There were no significant differences in soil compaction as measured by vertical penetrometer and bulk density. Pocket penetrometer readings indicate greater compaction in the standard versus O.B.A.T.A. management plots, below the topsoil.
- Most of the O.B.A.T.A. farmers kept a fair amount of crop residue cover on both their standard and O.B.A.T.A. fields (over 50% on average). Two farmers used aeration tillage in the fall regularly, and another was a no till farmer.
- Microbial biomass measurements taken in 1991 were similar to baseline measurements obtained in 1989. Fields with the greatest biomass carbon counts have a history of intensive soil management (i.e. use of manures, cover crops, and kelp and sugar additions etc.). Over the three year period no significant increases in microbial measurements were detected in the O.B.A.T.A. plots when compared with the standard plots.

Crops

- Winter wheat trials were only possible in 1989. Yields were greater on O.B.A.T.A. management plots compared with yields obtained from standard management plots. This may have been a positive response to foliar spraying as this was the only O.B.A.T.A. practice implemented on these fields at that time.
- No measurable differences in soybean yields on O.B.A.T.A. treatment plots in 1989, 1990 and 1991 could be discerned from those yields obtained from standard management plots.

* Corn yields on O.B.A.T.A. treated plots were greater (6%) than standard management plots, based on examination of three fields in 1991. During the first two years O.B.A.T.A. plot yields were slightly lower than those on standard treatments.

* The use of cover crops and aeration tillage (Aer-way®) systems were highly effective in reducing water runoff, soil, sediment and phosphorus losses.

Economics

* There are risks in changing farming practices. While farmers are motivated by environmental and health concerns, an economic incentive is also an excellent motivator. Observations, consideration of inputs and returns have been evaluated in year three and the results show O.B.A.T.A. practices are comparable or superior to conventional practices in terms of economics.

Other

* Soil micro-faunal populations within plots with added kelp and sugar versus standard management plots indicated no significant differences in a one year study.

* The use of kelp, molasses and other sugars, and 71B fertilizer solution as a seed and foliar treatment in an aeration tillage system does not significantly affect growth or yield of soybeans, based on a two year micro-plot study. Nevertheless, positive responses to these additives were evident on some field scale treatments.

This on-farm research has proven to be very effective in testing and demonstrating alternative production practices. Considerable effort is required in the initial year of such an undertaking to establish good communication and understanding between researchers and farmers. Subsequently, attention is needed to continue consistency and integrity of practices and statistical design. It would be desirable to have at least ten participants to improve the statistical component.

Longer term research is essential for studies of this nature. Both the farmers and researchers agree that the third year is really the first year of reliable data, considering the adjustment period needed for transition in soils, weed control and experience of the co-operator.

An extension component should be added to projects of this type. In the final year of study, Can-Ag Enterprises received funding from SWEEP and Aer-way® to produce a video that could be appropriate for extension use.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

LOSS OF NITROGEN BY MICROBIAL DENITRIFICATION, NITRIFICATION, SURFACE AND TILE RUNOFF: RELATION TO TILLAGE METHOD

FINAL REPORT

May, 1992

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EXECUTIVE SUMMARY

Concerns over contamination of natural water systems and rising costs of production in the agriculture industry have led to increasing use of conservation tillage methods as a means of reducing these effects. Reduced tillage, however, also affects water movement, aeration and N-transformations in soils. A simplified N-cycle diagram for soils is shown in Figure 1. The research described in this report was focused on several of these aspects as summarized below:

1.1 NITRATE LOSS IN SURFACE AND TILE RUNOFF WITH CONSERVATION AND CONVENTIONAL TILLAGE

Nitrate concentrations and total volume of surface and tile runoff from conventional (moldboard plow) tillage (CT), no-tillage (NT), ridge tillage (RT) all planted in continuous corn, and Kentucky bluegrass (BG) treatments, were measured over three years, 1989 to 1991. All corn tillage treatments received a total of 178.6 kg N ha^{-1} annually over the growing season. The volume of water drained through the tiles in the corn tillage systems always exceeded the volume in surface runoff, typically by factors of 2 to 4. Tile outflow was greatest from the CT treatments, least from BG and approximately equal from RT and NT treatments in 1989 and 1990. Concentrations of NO_3^- in tile water from CT, RT and NT treatments exceeded the maximum recommended safe limit of 10 mg N L^{-1} in 79% of runoff events with flow-weighted concentrations between 12 and 17 mg N L^{-1} in 1989 and 1990. Flow-weighted NO_3^- concentrations were only 1.2 and 2.6 mg N L^{-1} from BG in 1989 and 1990 respectively. The total NO_3^- lost in tile water in 1989 was 18, 14, 14 and 1 kg N ha^{-1} from the CT, RT, NT and BG treatments, respectively, whereas in 1990 there was 29, 20, 20 and 3 kg N ha^{-1} lost from the CT, RT, NT and BG treatments. Nitrate losses in surface runoff were lower than tile runoff with maximums of 2.6 kg N ha^{-1} for the RT and NT treatments in 1989 and 5.5 kg N ha^{-1} for the RT treatment in 1990. In 1989 and 1990, both RT and NT treatments had greater yields and N-uptake than the CT treatment. A serious drought in 1991 limited corn yield, N uptake and NO_3^- loss.

1.2 BACKGROUND AND POTENTIAL DENITRIFICATION VARIATION WITH DEPTH UNDER CONSERVATION AND CONVENTIONAL TILLAGE

Background and potential denitrification was measured in Brookston clay soil at depths to 0.9 m under several conservation tillage plots and a conventional moldboard plow tillage plot. The objective was to identify possible effects of the various tillage treatments on denitrification and on NO_3^- loss. Background denitrification (NO + N_2O) was estimated in intact cores in 1989 and 1990 using a gas flow-through system which permitted net NO and N_2O production rates to be measured. Rates decreased with increasing depth under all tillage treatments but no correlation was evident between background denitrification and tillage, perhaps due to the large spatial variability observed. Potential denitrification estimates were made using excess added NO^-_3 and the C_2H_2 blockage method (Yoshinari, *et al*, 1977). Estimates were obtained in 5 cm increments to a depth of 0.9 m. In all cases the top 5 cm increment showed highest potential for denitrification. Among the tillage treatments the highest potential was with the no-till Kentucky bluegrass plot and intermediate potentials in ridge till and no-till corn plots and lowest in the conventional till plot. Carbon dioxide production, NO_3^- and NH_4^+ levels followed the same pattern with depth. The relatively low denitrification potential below the uppermost soil layer suggests that in these plots denitrification would not be expected to greatly ameliorate NO_3^- loss by leaching.

1.3 NITRIC OXIDE AND NITROUS OXIDE PRODUCTION: WATER AND OXYGEN EFFECTS

This study was designed to determine the effects of water and O_2 on the speciation of denitrification gases (NO and N_2O). Nitric oxide was found to be the principal end product from soil incubated under low moisture conditions, whereas the relative amount of N_2O increased under wetter moisture regimes. The total amount of NO plus N_2O produced increased with increasing water content for the Brookston clay loam whereas it peaked at 15% water content with the Fox sandy loam. The decrease in NO plus N_2O at higher water contents was probably the result of the subsequent reduction of N_2O to N_2 in the Fox sandy loam soil. The residence time of the denitrification gases in the soil increased with increasing water content, hence facilitating the subsequent conversions of NO to N_2O and N_2. The thickness of the water film surrounding the microbes affected both the diffusion of O_2 through the water and into the microbes as well as the diffusion of denitrification gases (NO, N_2O, and N_2) from the microbes into the atmosphere. In the sandy loam soil, O_2 content and soil water affected both the amount and species of evolved denitrification gases. Oxygen was more effective in decreasing NO production at lower than at higher water contents.

2.1 IMPLICATIONS

Although conservation tillage (RT and NT) decreased the concentration and total loss of NO_3^-, the concentrations generally exceeded the 10 mg N L^{-1} recommended limit. Further reduction could perhaps be achieved through use of cover crops, intercrops or controlled drainage systems. In conservation tillage systems, particularly RT, losses of N by denitrification would likely be reduced if nitrogen fertilizer was added below the surface 5 cm zone. Since tillage influences water infiltration and storage and the aeration status of the soil, the overall denitrification rate is affected as well as the ratio of NO:N_2O. Thus tillage indirectly affects the environmental impacts of these important atmospheric trace gases, and also contributes to the observed large spatial variability in flux of these gases from soils. Greater levels of NO evolve from drier soils and relatively greater levels of N_2O from wetter soils. Under all tillage systems both background and potential denitrification decreased markedly with depth reflecting low denitrifier populations below the surface layer. Hence in the plots used in this study, denitrification would not be expected to greatly ameliorate loss of NO_3^- by leaching.

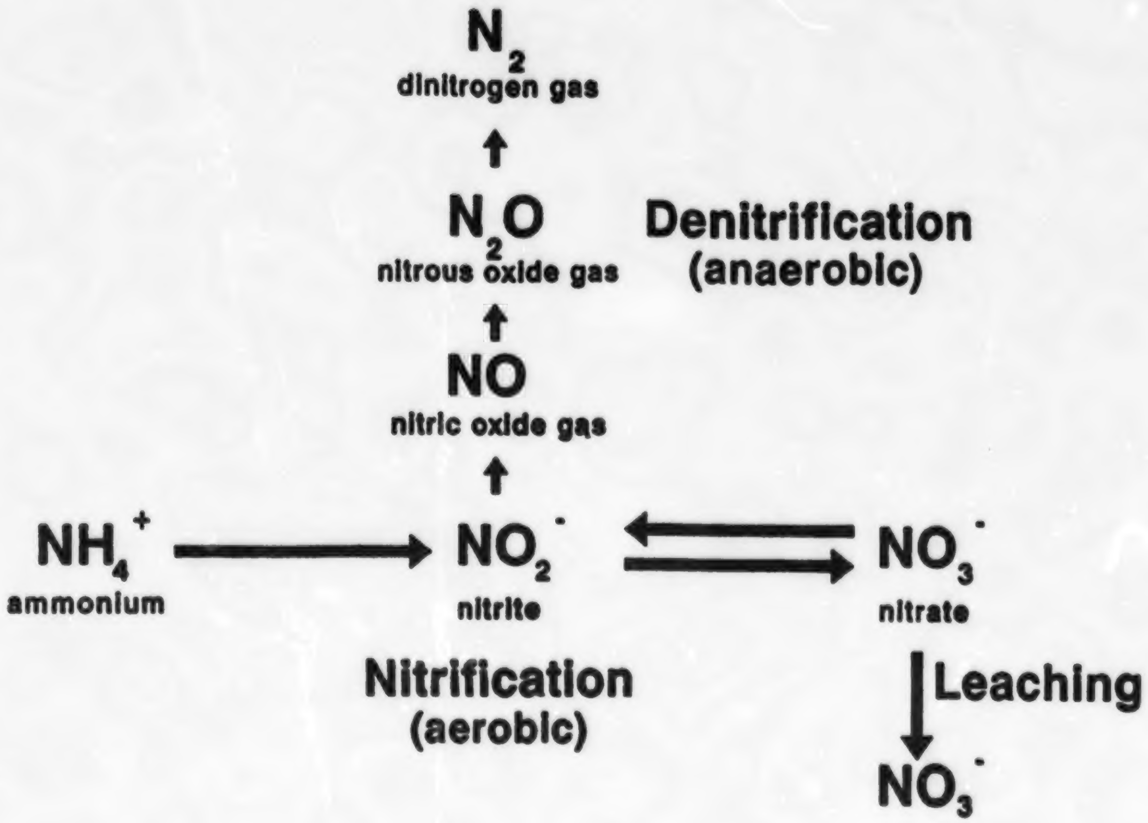
N_2
dinitrogen gas
N_2O
nitrous oxide gas
Denitrification
(anaerobic)
NO
nitric oxide gas
NH_4^+
ammonium
NO_2^-
nitrite
NO_3^-
nitrate
Nitrification
(aerobic)
Leaching
NO_3^-

Figure 1. A simplified N cycle diagram for soils.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

FIELD SCALE TESTS OF COVER CROPS I AND II

FINAL REPORT

May, 1992

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Disclaimer:	The views contained herein do not necessarily reflect the views of the Government of Canada or the SWEEP Management Committee.

EXECUTIVE SUMMARY

During 1990-1991 three separate field scale cover crop trials were conducted in Middlesex, Perth and Huron counties in southwestern Ontario. The first trial looked at broadcasting barley and annual ryegrass into corn when the corn was at approximately the twelve leaf stage. This study was located at five locations, two of which were managed in an organic fashion and the remaining sites were band sprayed. The second area of study looked at seeding spring cereals (oats and barley) into soybeans at 10% leaf drop and prior to harvest. A total of five cooperators participated in this part of the study. The following year, 1991, the best performing treatments from the forementioned studies were carried one step further. This trial examined seeding rates of 1/2X, 1X and 2X the recommended rate for annual ryegrass broadcast into corn and barley and oats seeded into soybeans at 10% leaf drop. A total of nine sites were involved in this project.

More than adequate rainfall was received around the time of cover crop application in 1990. However in 1991 insufficient precipitation levels were recorded at this time which had a dramatic effect on the performance of the cover crops, especially the annual ryegrass.

In both years, the spring cereals applied into soybeans at 10% leaf drop at the recommended rate increased residue levels by late fall relative to soybean stubble alone. Oats performed slightly better than barley in 1990 with the opposite occurring in 1991.

Practical considerations related to labour needs, weather and the timing of cover crop establishment for adequate fall growth did not favour the planting of spring cereals prior to soybean harvest.

In the first year annual ryegrass underseeded into corn produced considerably more top growth than either of the barley treatments by late fall. Due to lack of rainfall the annual ryegrass treatments in the second year performed at less than a satisfactory level.

The soybeans were slightly damaged at time of application as the cooperators tractor, mounted with a seed broadcaster, was used to apply the seed. The main crop yields in the cover crop establishment year or the subsequent year were not significantly affected by any of the cover crop treatments.

Taking into consideration residue levels, rainfall simulation results and seed costs the annual ryegrass applied at the recommended rate of 15 kg/ha would be the choice of most producers.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

PHOSPHORUS MOVEMENT IN SOIL AS A FUNCTION OF PHOSPHORUS SOLUBILITY AND REACTIVITY

FINAL REPORT

May, 1992

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EXECUTIVE SUMMARY

To investigate the possible role of crop residues on the release of soil phosphorus and its effect on crop growth, a series of three experiments were performed. An acidic soil (Welland Series), pH 5.3, from the Niagara region of southern Ontario was limed to pH's 6.4 and 7.5 by addition of two rates of lime, $CaCO_3$. Corn residues were either added directly to the soil surface or were incorporated into the soil. The experiment consisted of nine treatments;- three soil treatments - control, surface applied residue and incorporated residue, and three pH values - 5.3, 6.4, 7.5. Barley was grown in the various soils in a greenhouse. The plants were harvested at two different growth periods, corresponding to Feeke's stages 3 and 6. Both plant and soil analyses were performed.

There were differences in the yield of barley between the control soil and the two residue treatments. These differences in yield however were not significant at the first harvesting period. Final yields at the later harvesting were significantly lower in the control than in the two residue treatments at the two lower pH values but the effect of the residue treatments on final barley yields disappeared in the soil limed to a pH of 7.5.

The increased yield for the residue treatments did not appear to be due to an increased content of tissue phosphorus. The increased plant yields appeared to be more directly related to increased tissue potassium content at the earlier date of harvesting and to an increased tissue nitrogen content at the later harvesting date.

The increased yields also corresponded to increased soluble carbon contents in the extracted soil solutions and therefore it is possible that the degradation of the corn residues either at the soil surface or directly incorporated into the soil released soluble nitrogen and potassium, in addition to soluble phosphorus. Although there was some evidence for increased soluble phosphorus contents in the extracted soil solutions these increases were not significant.

In a second experiment, the soils with the three different pH values were incubated with incorporated corn or alfalfa residue over a period of forty eight days. At various time intervals the soil solution were extracted and analyzed for soluble organic carbon and phosphorus.

Incubation with either corn and alfalfa residues lead to an increase in soluble organic carbon, soluble total phosphorus and ortho-phosphate. The maximum amounts of each of the constituents occurred at after two to three weeks, with contents of the constituents being released over a longer time period for alfalfa than for corn. Because of uncertainties in the exact nature of total phosphorus measured by the ICP-AES technique, it was not clear whether this increase in phosphorus content is due to the release of mineral-bound phosphorus or due to an increase in organic phosphorus. An automated procedure for determining both inorganic and organic forms of soluble phosphorus was developed in the latter stages of this work - see Appendix I.

In the third experiment, the soils were shaken with phosphate in the presence and absence of different naturally occurring organic acids. It was shown that retention of phosphorus was less in the presence of these acids and that those organic acids that form strong bonds with the surfaces of soil particles were the most effective in reducing specific adsorption of phosphate.

This study has shown that there is an increase on crop yield if soils at three different pH's are amended with crop residues either applied at the soil surface or incorporated into the soil. Incubation of the soils with either corn or alfalfa residues increases the amount of soluble phosphorus in the soil solution after about two to three weeks of incubation. With increased time however the content of soluble phosphorus decreases. This increase in soluble phosphorus is probably due in part to release of inorganically and organically bound phosphorus from the crop residues and, as the final part of the study has shown, to release of soil bound phosphorus by the increased concentration of released organic acids.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

RAINFALL SIMULATION TO EVALUATE EROSION CONTROL ON TED RESEARCH SITES

FINAL REPORT

July, 1992

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EXECUTIVE SUMMARY

Rainfall simulations were conducted in 1989, 1990 and 1991 on twenty two occasions at fourteen different farms. A wide range of conservation farming systems, involving different tillage, cover crop and manure management systems, were evaluated in terms of runoff and soil and phosphorus losses resulting from a simulated rainstorm.

The rainfall simulations took place on research plots set up within ongoing TED studies, following consultation with the TED research contractor and the farmer cooperator. Runoff and erosion data were collected within one set of replications set up under the main research trials.

The erosion control offered by aeration tillage, reduced tillage (using a chisel plow or offset disk) and zero-tillage systems was evaluated, and compared against a conventional (moldboard plow) tillage system. At some sites, the erosion control provided by cover crops of red clover, rye, barley, annual ryegrass, hairy vetch or oilseed radish was compared against treatments where the only surface residue cover was from the previous main crop. The susceptibility of soils to erosion and phosphorus losses following applications of raw and composted beef manure, and liquid swine manure was also examined.

The runoff and erosion data provided by the rainfall simulations were highly variable at many of the sites. However several trends emerged from the research. In most cases, the conservation tillage systems resulted in reduced runoff and erosion rates. Aerway®[1] tillage shows promise as an effective management tool for high residue cropping systems. It leaves sufficient residue on the surface to reduce the amount of soil detachment and erosion due to rainfall, and does not appear to lower the infiltration rates in comparison with moldboard plow tillage, as indicated by runoff volumes. Furthermore, it can be pulled in tandem with the planter, providing secondary tillage with relatively little soil disturbance.

Reduced tillage systems tended to lessen the amount of sediment loss due to the simulated rainstorm, in comparison with moldboard plow tillage. In most cases, the degree of control over sediment losses was proportional to the amount of residue cover remaining on the surface and the amount of disturbance to the soil surface by the tillage operation.

Many cover crop systems were tested by rainfall simulation. When they were growing, or had been killed but not disturbed by tillage, they provided nearly complete surface cover and appeared to be equally effective in controlling soil erosion. After spring cultivation and planting, some cover crops, most notably hairy vetch, appeared to provide lasting erosion control benefits, possibly due to soil structural improvements and persistent surface residue. Other cover crops, in particular oilseed radish, provided no lasting erosion control benefits. In general, the residue from cover crops with more fibrous plant growth was more persistent and effective in controlling soil erosion.

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[1] inclusion of brand names does not imply endorsement of use.

Applications of raw and composted beef manure in summer onto perennial forages and applications of liquid swine manure in summer and spring did not affect erosion rates or phosphorus losses in comparison with similar treatments where manure was not applied. However, when poultry manure was applied in the fall and incorporated by aerway tillage only, soluble orthophosphate-P losses by rainfall simulation were very high (3.6 mg/m^2) in comparison with losses of 0.13 mg/m^2 when the manure was incorporated by moldboard plowing.

Several factors contributed to high variability or possible non-treatment related differences in the rainfall simulation results. Soil cracks on some plots caused major reductions in runoff. Due to the experimental set-up, the slopes of some treatments were significantly different than the slopes of the treatments to which they were being compared. Nevertheless, many of the rainfall simulations provided excellent results and demonstrated that reductions in soil and phosphorus erosion can be achieved by the adoption of conservation farming measures.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

SOIL LOSS BY TILLAGE EROSION: THE EFFECTS OF TILLAGE IMPLEMENT, SLOPE GRADIENT, AND TILLAGE DIRECTION ON SOIL TRANSLOCATION BY TILLAGE

FINAL REPORT

June, 1992

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Disclaimer:	The views contained herein do not necessarily reflect the views of the Government of Canada or the SWEEP Management Committee.

EXECUTIVE SUMMARY

In the preceding study entitled "Management of Farm Field Variability: II. Soil Erosion Processes on Shoulder Slope Landscape Positions" net downslope soil translocation by tillage, tillage erosion, was identified as a major cause of the severe soil loss observed on upper slope landscape position in the complex topography of southwestern Ontario. This study examined the processes of soil translocation and tillage erosion in greater depth than the preceding study. The effect of tillage implement type on the magnitude of soil translocation and net downslope soil translocation by tillage under a range of slope gradients within a typical upland landscape was examined. The effects of other factors such as soil conditions, tillage depth, and tillage ground speed were also examined.

Soil translocation by four tillage implements, chisel plow, moldboard plow, tandem disc, and C-tine cultivator, was measured on a range of slope gradients in both upslope and downslope directions on two topographically complex, but similar, field sites in Huron County. The soil texture of both field sites was sandy loam. Soil translocation was measured using the tracer-pulse method. Chloride was utilized as the labelling element to generate the tracer-pulse. Soil translocation was calculated using the synthetic step response distribution synthesized from a succession of convoluted Cl pulse response distributions. Soil loss caused by tillage erosion was measured as the net downslope soil translocation by tillage. Paired plots were utilized to calculate net downslope soil translocation from upslope and downslope tillage operations.

Measurements of soil translocation, net downslope translocation and soil loss for all four tillage implements and for treatments of tillage implements were characterized as highly variable. The consequence of this variability was that soil loss and accumulation were observed throughout the topography, regardless of slope position. Although this variability existed, net soil losses were observed on the upper slope landscape positions for all four tillage implements, indicating that less soil is translocated upslope than downslope by each tillage implement. The chisel plow, moldboard plow, tandem disc and cultivator all caused tillage erosion which resulted in soil loss.

Measured soil losses resulting from two passes, one upslope and the second downslope, of the chisel plow, moldboard plow, tandem disc and cultivator, when averaged over the linear and convex upper slope landscape positions, were 0.19 kg m^{-2}, 0.05 kg m^{-2}, 0.43 kg m^{-2}, and 0.54 kg m^{-2}, respectively. Assuming each tillage operation is conducted upslope and downslope equally as often, the average soil losses per tillage pass for the chisel plow, moldboard plow, tandem disc and cultivator, were estimated to be 0.09 kg m^{-2} (0.9 t ha^{-1}), 0.03 kg m^{-2} (0.3 t ha^{-1}), 0.22 kg m^{-2} (2.2 t ha^{-1}), and 0.27 kg m^{-2} (2.7 t ha^{-1}), respectively.

Maximum measured soil losses between plots within the upper slope landscape positions resulting from two passes, one upslope the other downslope, of the chisel plow, moldboard plow, tandem disc and cultivator were 2.96 kg m^{-2}, 4.34 kg m^{-2}, 1.14 kg m^{-2}, and 2.97 kg m^{-2}, respectively. Assuming each tillage operation is conducted upslope and downslope equally as often, the maximum soil losses per tillage pass for the chisel plow, moldboard plow, tandem disc and cultivator, were estimated to be 1.48 kg m^{-2} (14.8 t ha^{-1}), 2.17 kg m^{-2} (21.7 t ha^{-1}), 0.57 kg m^{-2} (5.7 t ha^{-1}), and 1.49 kg m^{-2} (14.9 t ha^{-1}), respectively.

The range between minimum and maximum values of soil translocation for each tillage implement provided indicators of potential net downslope soil translocation. The ranges for the chisel plow, moldboard plow, tandem disc and cultivator were 33.6 kg m^{-1}, 38.5 kg m^{-1}, 26.9 kg m^{-1}, 20.0 kg m^{-1}, respectively. The potential soil losses from the upper slope landscape positions, based on these ranges, for the chisel plow, moldboard plow, tandem disc and cultivator were estimated to be 0.51 kg m^{-2}, 0.60 kg m^{-2}, 0.55 kg m^{-2}, 0.47 kg m^{-2}, respectively. Assuming each tillage operation is conducted upslope and downslope equally as often, the potential soil losses per tillage pass for the chisel plow, moldboard plow, tandem disc and cultivator, were 0.26 kg m^{-2} (2.6 t ha^{-1}), 0.30 kg m^{-2} (3.0 t ha^{-1}), 0.28 kg m^{-2} (2.8 t ha^{-1}), and 0.29 kg m^{-2} (2.9 t ha^{-1}). Maximum absolute values of net downslope soil translocation for each tillage implement also provided indicators of potential soil loss. The maximum absolute values for the chisel plow, moldboard plow, tandem disc and cultivator were 30.4 kg m^{-1}, 17.8 kg m^{-1}, 26.9 kg m^{-1}, 14.6 kg m^{-1}, respectively.

All four tillage implements are considered erosive however, the relative erosivity of the four implements could not be assessed conclusively because of the variability in the data. These observed values of soil loss are relatively small, but exceed acceptable limits. The rate of soil loss within complex topography is clearly scale dependent.

The results indicated that there are relationships between soil translocation and slope gradient, tillage depth and tillage ground speed, however, these relationships are not always strong nor are they consistent between tillage implements, or within tillage treatments of tillage implements. There was some indication that soil translocation increased as slope gradient, tillage ground speed, and tillage depth increased. There was also some indication that ground speed increased as slope gradient increased, that ground speed decreased as tillage depth increased, and that tillage depth increased as slope gradient increased.

The inconsistency in these relationships suggests that there are other factors involved in the translocation of soil by tillage other than slope gradient, tillage depth and tillage ground speed. The shape and arrangement of tillage tools, and the responsiveness of tillage operator, as well as slope gradient, tillage depth and tillage ground speed, may also affect soil translocation. In theory, the volume of soil translocated is determined by the tillage depth and the shape and arrangement of the tillage tools; the mass of soil translocated is determined by the soil bulk density; and the extent of the translocation is determined by the shape of the tillage tools, the ground speed of the tillage implement and the slope gradient. The tillage operator continuously adjusts both tillage depth and tillage ground speed, through the adjustment of gear ratio, to compensate for the effect of gravity on the mass of the tillage equipment as it moves through the landscape. The degree to which the operator has to adjust tillage depth and ground speed will depend on the tractor-implement match.

The implications of this study reaffirm the implications of the preceding study "Management of Farm Field Variability: II. Soil Erosion Processes on Shoulder Slope Landscape Positions" by Kachanoski et al. (1992b). In brief, those implications were: 1) soil loss caused by tillage erosion is not restricted to shoulder slope landscape positions; 2) predictive soil loss and crop productivity models that do not include the process of tillage erosion do not represent reality on cultivated agricultural land in complex topography; and 3) preventative and corrective soil loss measures that do not include the reduction of tillage erosion will not be effective in controlling soil loss on upper slope landscape positions of cultivated agricultural land.

Implications arising directly from this study include: 1) factors affecting tillage erosion include not only slope gradient and curvature, tillage depth, tillage ground speed and soil conditions, but also tillage tool shape and arrangement, tractor-implement match and the response of the tillage operator to changing slope gradient; and 2) studies which examine single tillage operations of specific tillage implements with limited replications have the potential to generate highly variable data due to the numerous factors involved, resulting in observations of soil loss and soil accumulation throughout the topography.

Recommendations to reduce tillage erosion induced soil losses on upper slope landscape positions in the upland regions of southwestern Ontario were outlined in the preceding study "Management of Farm Field Variability: II. Soil Erosion Processes on Shoulder Slope Landscape Positions" by Kachanoski et al. (1992b). In brief, those recommendations were: 1) reduce tillage frequency; 2) reduce tillage intensity; 3) reduce the size of tillage implements; and 4) vary tillage patterns within fields. All four tillage implements were found to be erosive, but it could not be concluded which of the above recommendations would provide the greatest reductions in soil loss resulting from tillage erosion.

Recommendations for further research are: 1) develop a practical and accurate method of measuring tillage depth for both primary and secondary tillage operations; 2) conduct more rigorous studies of the effects of slope gradient and curvature, tillage depth, and tillage ground speed on soil translocation and tillage erosion; 3) examine the role of tillage tool shape and arrangement, tillage operator, and tractor-implement match on soil translocation and tillage erosion; 4) examine soil translocation and tillage erosion under a broad range of soil conditions to determine the effects of soil texture and soil moisture content on soil translocation.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

YIELD REDUCTION EFFECTS OF CROP RESIDUES IN CONSERVATION TILLAGE

FINAL REPORT

June, 1992

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EXECUTIVE SUMMARY

FIELD STUDIES

The presence of crop residues on the soil surface in conservation tillage systems affected soil water content and temperature,and plant growth. When the spring season was dry, residues retarded evaporation resulting in soil temperatures cooler in comparison to a conventional tillage system. However, the extra water retained in the soil also promoted plant growth. During a wet season, plants appeared pale and growth was stunted due to cooler soil temperatures and wetter soils. Nevertheless, soil temperature and moisture measurements could not totally explain the reduction observed in corn plant development in the presence of specific plant residues, particularly residues of red clover and canola.

Phenolic acids (PCs) and volatile fatty acids (VFAs) generally were not found in concentrations considered to be phytotoxic in field soil samples. Field sampling in the spring showed the presence of PCs which tended to decrease in concentration from May to June. However, within 48 hours after a 40 mm rainfall event in late June, PCs were detected in plots with residue cover. The presence of VFAs was detected only once during the three years of study in the field. This was after a shower in early June from a plot receiving rye residues (4 t ha^{-1}).

The addition of calcium nitrate to soil amended with crop residues significantly reduced accumulation of VFAs in a laboratory study. However, under field conditions the addition of calcium nitrate with the seed did not overcome the yield reduction effects of rye residues.

LABORATORY STUDIES

The production of VFAs is dependant on the nature of the crop residue, soil water content and temperature. Green, readily decomposable residues such as legumes had the greatest potential for the accumulation of VFAs when soil temperatures were high (15-25°C) and soil water potential was above field capacity. The potential for VFA production decreased as the plant materials matured to harvest stage and underwent weathering.

There was little difference in the accumulation of VFAs under soil moisture conditions ranging from field capacity to saturation. Phytotoxic concentrations could be produced in the laboratory within 48 hours of incubation, a period which could be expected in the field.

The accumulation of VFAs was much greater at high temperatures (25°C) than at low temperatures (4°C). During incubations there was a lag period of about 2 days followed by a rapid increase in VFA accumulation to a maximum at about 14 days. This was followed by a rapid decrease in soil VFA concentration indicating that these compounds were readily utilized by soil microorganisms. A second but much smaller peak was observed on day 28, especially for rye and soybean residues. Under low temperatures (4°C), VFA accumulations were small but steady over the entire incubation period. Total phenolic concentrations were never as high as those found for VFAs. This may be because VFAs are a by-product of anaerobic decomposition whereas PCs are released as the residue undergoes decomposition.

Bioassays using corn and winter wheat were performed to assess phytotoxic affects. Selected VFAs and PCs inhibited germination and early growth of corn, although not all hybrids were affected equally. Phytotoxicity increased with decreasing solution pH. Combinations of the phenolic acids appeared to affect corn radicle growth in a non-additive manner.

The winter wheat bioassay showed that VFAs were more inhibitory to plant growth than PCs. Acetic acid was inhibitory to both radicle and coleoptile growth, irrespective of crop variety or VFA concentration tested. Propionic and butyric acid also inhibited plant growth but to a lesser extent than acetic acid. Vanillic acid was inhibitory to germination and early seedling growth whereas *p*-hydroxybenzoic acid and *p*-coumaric acid stimulated early seedling growth.

In conclusion, the field research indicates that phytotoxins are produced from decomposing crop residues which can significantly reduce plant growth. However, the nature of these phytotoxic compounds is not clear. VFAs and PCs accumulated in the soil to phytotoxic concentrations during the decomposition of particular crop residues in laboratory studies. However, these compounds were not detected in field studies. Future research should consider the dynamics of both the production and utilization of phytotoxin compounds during decomposition of crop residues. In addition, there is a need to examine other potential phytotoxins, such as the volatile C_6 through C_9 organic compounds.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

FIELD TESTING OF COVER CROP SYSTEMS FOR CORN AND SOYBEAN PRODUCTION

FINAL REPORT

June, 1992

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Executive Summary

Experiment 1. Field Testing of Cover Crop Systems

Promising cover crop species including hairy vetch, oilseed radish and winter rye were evaluated on 6 farms in South Western Ontario. Cover crops proved to be economical by either reducing production costs or increasing yields. Oilseed radish appeared to be the most promising new cover crop as it showed potential to reduce production costs, improve weed control and increase corn yields. Hairy vetch provided similar yields and input costs as red clover when used as a legume cover crop prior to corn. Promising rye management systems included using winter rye as a double crop forage before conventionally planted soybeans and using winter rye as a weed suppressing mulch for no-till soybean production.

Experiment 2. Evaluation of the N Contribution of Cover Crops using a Nitrogen Soil Test

Corn grown on plots fertilized with manure and/or cover crops (oilseed radish, red clover and hairy vetch) were sampled biweekly after planting to determine spring soil N transformations and to determine if the N soil test (taken in the top 30 cm of soil at time of sidedress) was a useful indicator of N availability from these sources. Other researchers working in the U.S corn belt have shown that 21 ppm NO_3-N is the critical N level, above which no N fertilizer response is observed, when legumes and manure are the N sources used for corn production. In this study, N fertilization of sites having NO_3-N levels of 23 ppm produced a corn yield response at two sites. A value of approximately 25 ppm NO_3-N appeared to be a better indicator of fertilizer N response in this one year study. Use of a N soil test appears to be a valuable tool in identifying sites which have an excess supply of N, rather than predicting fertilizer N requirements. It could be a useful tool in helping farmers better understand and manage the N cycle on farms with cover crops and manure as N sources.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

EFFECT OF WINTER RYE MULCHES AND FERTILIZER AMENDMENTS ON NUTRIENT AND WEED DYNAMICS IN NO-TILL SOYBEANS

FINAL REPORT

June, 1992

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Disclaimer:	The views contained herein do not necessarily reflect the views of the Government of Canada or the SWEEP Management Committee.

Executive Summary

In the early 1980's, weed scientists' identified winter rye to be an effective weed suppressing mulch for no-till production systems. The term allelopathy is frequently used to describe the weed suppressing effect of the winter rye. However, comprehensive field data supporting allelopathy as a major mechanism of weed suppression for high C:N ratio cover crops such as winter rye is lacking. No studies in the literature could be identified which examined the effect of a winter rye cover crop on soil nutrients and weeds. However, a number of studies by soil scientists have recently indicated that rye cover crops reduce soil nitrogen. As well, weed scientists have identified that some annual weeds are more responsive to high soil nutrient levels than other weeds or crops.

This study examined if rye cover crops contribute to weed suppression in no-till systems by reducing soil nutrient levels and hence weed pressure from N responsive annual weeds. Experiments were conducted to examine: 1) the mulch (or physical) effects and 2) the fertility effects of a no-till rye cover crop on nutrient and weed dynamics in no-till soybeans. The objectives were to: 1) identify the effects of a rye cover crop on soil nutrients and 2) to separate the nutritional effects from physical and chemical (allelopathic) ones that are responsible for weed suppression in no-till soybeans.

Soil nutrient data indicated that rye plots had low soil nitrate levels at the time of soybean planting but nitrogen levels in control plots were also relatively low when measured shortly after planting. Soybeans sampled 4 weeks after planting showed delayed growth where rye had been planted as a fall cover crop in both experiments. However, nutritional deficiencies in the soybeans were not evident 8 weeks after soybean planting in both experiments. In the mulch experiment, rye cover crops grown in place and left in place (providing physical, chemical and soil nutrient effects of a mulch) resulted in approximately 1/5 the weed biomass of bare plots (no mulch) and 1/3 the weed biomass of: a rye mulch moved in place (providing physical and chemical effects of a rye mulch); a poplar excelsior mulch moved in place (providing a physical effect of a mulch) and a plot in which the rye was grown in place but removed after soybean planting (providing a soil nutrient effect of a mulch). In the fertility experiment, the addition of 75 kg N/ha to the rye plots increased weed growth by 400% and caused lamb's-quarters to become a major weed species.

In summary, one of the weed suppressing characteristics of a rye cover crop appeared to be related to its' effect on nutrient availability. The physical mulch effect also appeared to be significant in reducing weed biomass. This study indicated that these two mechanisms together play an important role in providing weed control for farmers developing low herbicide, soybean no-till systems.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

MANURE MANAGEMENT IN CONSERVATION FARMING

FINAL REPORT

June, 1992

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Executive Summary

The agronomic use of manure was evaluated in four major field crops in Southern Ontario (corn, soybeans, winter wheat and alfalfa) over a three year period (1989-91). The principle objective of the research was to identify manure management systems which minimize environmental pollution and result in good agronomic yields of the crops being evaluated. The experiments were conducted on farms with the active participation of four farmer cooperators.

The overall approach in the research trials was to apply manure either :

1) prior to the seeding of a fast growing cover crop and subsequently establish the main crop using a conservation tillage system or,
2) directly to an established crop prior to a period of high biomass accumulation in the crop.

Individual findings from the experiments are summarized below.

Experiment 1. Effect of Oilseed Radish, Timing of Manure Application and Tillage System on Nutrient Cycling and Corn Performance (Within a Winter Wheat Corn-Sequence)

Spring liquid manure applications resulted in higher N availability in corn than manure applied during the late summer of the previous year. Seeding of an oilseed radish catch crop following the summer manure application improved nutrient cycling. Oilseed radish took up approximately 100 kg N, 15 kg P and 125 kg K from the soil in the fall. The potential for fall nitrate leaching potential was reduced by the oilseed radish as soil nitrate levels (at 4 sites) and soil moisture levels were lowered (at 1 site). In 1990, oilseed radish caused a temporary immobilization of P in 1990 at the silt loam site which was observed as tissue P levels in whole corn plants harvested at the 5 leaf stage. Potassium uptake was lowest in plots where corn was no-tilled into oilseed radish residue and highest where oilseed radish was plowed in the previous fall. Use of oilseed radish generally increased fall soil cover but tended to lower soil cover in the spring. Minimum tillage systems (Aerway and zero-till) were the most effective systems for maintaining residue cover and reducing runoff and soil loss. Tillage reduction improved P nutrition at the 5 leaf stage but reduced N and K uptake by corn at the ear leaf stage. Minimum tillage corn yields were generally competitive with conventional tillage systems when sufficient levels of N were available.

Experiment 2. Effect of Manure and Rye Cover Crop on No-Till Soybean Production

Application of solid manure prior to rye seeding appeared to have no positive effect on reducing nutrient deficiency problems being experienced in soybeans that were no-tilled into a winter rye cover crop. The main nutritional problems in soybeans appear to be N and P related. Rye cover crops depleted soil nitrogen at the time of rye seeding and reduced early season plant dry matter accumulation and nutrient content (N and P) of the soybeans. Early seeding of the rye provided very high ground cover and improved weed control over the late seeded rye. Use of liquid manure with winter rye probably would have been more appropriate as the solid manure applied in the present study contained large quantities of straw. Rye appears to be a promising no-till cover crop to reduce P surface loss because it has a high biomass yield, is slow to decompose, and has a low P content when killed at anthesis. Overall, the use of a rye mulch (particularly when the rye is killed at a late date) in no-till soybean production appears to hold significant potential as a means to reduce herbicide use, soil erosion, ground water loading of nitrates and surface nutrient loss. However, reducing nutritional effects of the rye mulch on soybeans needs to be resolved.

Experiment 3. Effect of Tillage System, Manure Form and Rate on Winter Wheat

Following soybeans, aerial seeding and no-till seeding of winter wheat resulted in equivalent wheat yields compared to conventionally seeded wheat. The main differences among the two conservation planting techniques was that aerial seeding provided greater ground cover (1990) and higher flag leaf N content (1991) than no-till seeding. This was attributed to the earlier establishment of winter wheat in the aerial seeded plots following the soybean crop. All three tillage systems resulted in high ground cover ratings (>50%) at the time fertility treatments were applied in late April. In both years, liquid swine manure applied at 40,000 l/ha to the provided equivalent winter wheat yields to nitrogen fertilizer. Mature compost applied on the surface at rates up to 15 t/ha did not increase yields compared to the control in 1989. Immature compost applied at rates of 40 t/ha increased wheat flag leaf N and P and wheat yield in 1990, but yields were lower than with liquid manure or fertilizer. In both years red clover fall biomass production was reduced and fall weed biomass increased with use of soluble N forms (liquid manure and fertilizer N). The immature compost increased wheat yield without affecting red clover biomass or fall weed growth. This was attributed to delayed nutrient release by the compost. Overall, the combination of no-till or aerial seeding wheat and low dose liquid manure applications appears to be a promising approach in the development of a low external input wheat production system that minimizes surface runoff risks.

Experiment 4. Effect of Solid Manure, Compost and Fertilizer on Established Forages

The annual application of low rates of solid manure (10 t/ha) or compost (7.5 t/ha) and fertilizer (0-30-135) moderately stimulated forage yields on an established alfalfa-timothy hay stand. All three fertilizer sources increased total forage yield but yields were highest when solid manure was applied. All three fertilizer sources increased alfalfa yield compared to the unfertilized control plot. As well, the solid manure treatment increased the grass yield of the forage stand which was responsible for the increase in total forage yield in this treatment. Throughout the course of the study, soil nutrient levels declined so that levels were very low at the end of the experiment. The fertility treatments did not maintain soil nutrient levels but delayed their decline. Overall, the risk of runoff and soil erosion from a perennial forage stand to which low rates of solid manure or compost had been applied appeared low.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

EVALUATION OF 58 COMMERCIAL CORN HYBRIDS (2850 TO 3450 C.H.U.) IN TWO CONSERVATION TILLAGE SYSTEMS COMPARED TO CONVENTIONAL TILLAGE IN KENT COUNTY, SOUTHWESTERN ONTARIO

FINAL REPORT

June, 1992

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EXECUTIVE SUMMARY

Various forms of mulch tillage systems, whether minimum, no-till (zone-tillage) or ridge-till, have increased rapidly in acreage across southwestern Ontario for corn production. Increased surface residue cover at planting time and earlier planting have been associated with both cooler seedbed environments and slower soil warming which have been shown to delay seed germination, emergence and crop development. It has been suggested that in a conservation tillage system uniquely different environmental stresses exist requiring corn hybrids with attributes uniquely different from those for conventional tillage systems. Currently all of the O.C.C. corn performance trial data is collected from conventional tillage systems insuring natural environmental stresses be maintained at a minimum.

Research from U.S.A. and Ontario has suggested that corn hybrids which perform well in conventional tillage systems may not perform satisfactorily under conservation tillage systems associating this difference to stresses due to increased residue and colder seedbed environment. Preliminary studies supported by TED and conducted by P.R.C. (Hope and Maamari) suggest the potential of developing a cold tolerance predictor for field emergence under conservation tillage management systems using the time to production of a 1 cm coleoptile under laboratory controlled cold (11° C til 1 cm coleoptile growth occurred) conditions.

The research reported in this report was initiated in 1991 at R.C.A.T. as a minimum 2-year study in co-operation with two local conservation tillage farming systems, Douglas Smith (ridge/strip) and Jack Rigby (zone-till). Fifty-eight corn hybrids from 18 seed companies were selected from the O.C.C. performance list which ranged from 2850 CHU to 3400 CHU and indexed 100 or better for yield in 1989 and 1990 O.C.C. performance trials. The hybrids were grouped into 3 maturity trials. Twenty-six in Early Season (2850-3050 CHU); 12 in Full Season (3075-3200 CHU); and 20 in Late Season (3300-3425 CHU). Each conservation tillage trial is being compared to the trial planted adjacent in a conventional tillage system. Seed from the same seed lot of each hybrid tested was made available to Hope at P.R.C. for cold tolerance predictor determination studies and also stored for 1992 field testing. Measured variables were: residue density, soil moisture, soil temperature, air temperature, time to coleoptile emergence, time to development of V-1 to V-5 leaves, percent emergence at V-3, percent final stand at harvest, days to 50% pollen shed and silk emergence, percent broken stalks, harvest grain moisture and grain yield.

The 1991 data is summarized within this report. The spring and early summer growing conditions for 1991 were unusually hot and dry failing to produce the required conditions to evaluate cold tolerance for emergence and early growth data. Consequently, the study will need to be continued a minimum of 2 more years (1992 and 1993) before field emergence data can be used to verify the usefulness of the Hope cold tolerance predictor for field emergence. The field data in this report is only one year's data from a very unusual growing season. This is considered a preliminary progress report and conclusions must not be made from such unusual and limited data.

The study is in progress for 1992 and 1993 with partial funding for 1993. In 1992, 28 new hybrids have been added for the field evaluation in separate trials under all four tillage systems. Seed from the same seed lots of these hybrids was sent to Hope at P.R.C. for cold tolerance testing.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

THE EFFECT OF CONSERVATION TILLAGE PRACTICES ON THE LOSSES OF PHOSPHORUS AND HERBICIDES IN SURFACE AND SUBSURFACE DRAINAGE WATERS

A: Soil Erosion, Phosphorus Losses and Corn Yield
B: Herbicide Losses

FINAL REPORT

May, 1992

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PART A - SOIL EROSION, PHOSPHORUS LOSSES AND CORN YIELD

EXECUTIVE SUMMARY

Deterioration of agricultural land by soil erosion and compaction has encouraged the use of conservation tillage with residue management in southwestern Ontario. Many types of conservation tillage systems have been developed but all are characterized by reduced tillage with over 30% crop residue on the soil surface. Zero and ridge tillage are examples of two conservation tillage practices which leave sufficient crop residue to reduce water flow velocities, increase water infiltration and produce less soil compaction. Conservation tillage has been shown to be effective in reducing soil loss by fluvial transport and in some cases increasing crop yield.

Phosphorus (P) in subsurface, surface and lake waters has been linked with algal blooms which impairs water use and can lead to shifts in aquatic species and populations. Phosphorus in subsurface and surface runoff from agricultural activities has been associated with sediment-phase transport. Thus, common belief held that a reduction in sediment transport would result in reduced phosphorus transport.

Southwestern Ontario is characterized as ideally suited for agricultural production because of its proximity to large U.S. and Canadian markets, adequate and well distributed rainfall, fertile soils and favorable climate for crop production. Because of its proximity to large populations and the largest freshwater resource in North America, past and current agricultural practices have been intensively investigated with respect to yield and to a lesser extent on impairment of water quality. A study was begun in 1984 to identify sediment and phosphorus transport from a poorly drained, Brookston clay loam soil, cropped to corn under three tillage practices. Water quality and yield from a conventional (fall plow, spring disk and midseason cultivation) tillage treatment,

was compared with that from a zero tillage (no tillage other than that associated with seeding and fertilizer application) and ridge tillage (ridges reformed in mid-season) treatment. Research results for the contract period January, 1988 to September 30, 1990 are reported herein.

Rainfall was measured with a rain gauge at the site to determine input. Surface and subsurface runoff for each runoff event was quantified from depth of water over a weir. Water samples were collected manually from each treatment throughout the hydrograph for sediment and orthophosphate analysis. Total soluble and sediment P were also determined over the three year period but an error in analysis invalidated the results for the 1988 and 1989 samples. These phosphorus forms were determined for the 1990 season. The sediment and orthophosphate concentrations were averaged within an event and event transport or loss was calculated from the product of average concentration of the component of interest and runoff volume. Annual losses were computed as the sum of event losses for the year. Surface and subsurface amounts were expressed as percent of total loss. The year was divided into three seasons, before planting (or fertilizer application, January 1 to planting), growing season (planting to September 30) and after harvest (October 1 to December 31). The seasonal losses were reported as a percent of total loss.

A wide range in climatic conditions from dry to wet growing season occurred over the duration of the study which affected grain yield, erosion and nutrient transport. Grain yield was similar within years from each of the tillage treatments. In 1988 (a dry year) and 1989 (a wet year) yields were low averaging 6 t/ha. In 1990 (a normal year) grain yield averaged 9 t/ha with slightly greater yield from the conservation tillage treatments than from conventional tillage. Conservation tillage has been reported to increase yield on well drained soil because of moisture conservation from crop residue but yield effects on poorly drained soils have been inconsistent and may be decreased. Excessive soil moisture during crop development as occurred in 1989, has been reported to reduce grain yield on Brookston soil.

Conservation tillage had a variable effect on sediment transport. In two of the three years, sediment transport was reduced by the conservation tillage treatments compared to that from conventional tillage. No tillage effects on sediment transport were observed in one year (1990) probably because no major runoff producing events occurred in the spring when soil erosion was most susceptible and sampling was terminated in September, 1990. Soil loss averaged over three years was 530±11 kg/ha from ridge tillage, 391±14 kg/ha from zero tillage and 897±14 kg/ha from conventional tillage. Zero tillage was more effective at reducing erosion than ridge tillage over the three years. A greater proportion of sediment transport occurred in surface runoff from the conservation tillage treatments whereas subsurface transport accounted for a greater proportion of sediment loss from conventional tillage. It is possible that much of the sediment transported through subsurface drainage from conventional tillage originated from preferential surface flow through cracks developed when soil moisture content was low.

Generally, dissolved (ortho) phosphorus transport was higher from zero tillage than from ridge or conventional tillage. Dissolved phosphorus transport was lowest from conventional tillage. Annual dissolved phosphorus transport ranged from 2.7 to 10.4 % of that applied from 1988 to 1990. Subsurface drainage accounted for greater than half of the orthophosphate loss from the conservation tillage treatments in two (1988 and 1990) of the three years. In 1989, surface runoff loss exceeded subsurface runoff loss of orthophosphate from zero tillage. Over 74% of orthophosphate transport from conventional tillage was from subsurface drainage in two of the three years. The seasonal loss pattern for dissolved phosphorus and water runoff were similar. The cumulative, three year sum of dissolved phosphorus transport was 74 to 174% higher from the conservation tillage treatments than from conventional tillage (1665±45 g/ha). Orthophosphate transport was 57% higher from zero than ridge tillage (2895±751 g/ha).

Preliminary studies indicated that total soluble P and total phosphorus (sum of sediment P and soluble P) transport was higher from the conservation tillage treatments than from conventional tillage. The proportion of soluble P transported as orthophosphate was less from ridge (47%) and conventional tillage (56%) than zero tillage (80%). Sediment phosphorus loss was similar between ridge and conventional tillage (199±14 and 197±43 g/ha, respectively) but higher from zero tillage (266±33 g/ha). Thus, much (84 to 93%) of the phosphorus transported from the conservation tillage treatments and conventional tillage occurred in the dissolved form. Other studies have shown that up to 98% of phosphorus transport may be associated with the sediment phase but that leachate from crop residue can account for considerable soluble phosphorus transported from conservation tillage treatments. Ridge reforming in ridge tillage may incorporate some of the crop residue with soil allowing for greater residue decomposition which could account for the greater release of soluble P from ridge compared to zero tillage. Sediment P and orthophosphate transport was higher from zero tillage than from ridge tillage because of P enrichment of runoff, but total P (the sum of all P forms) loss was higher from ridge tillage because of the greater proportion of other soluble P forms. Total phosphorus transport, assuming all P originated from fertilizer ranged from 7±0.3% from conventional to 15±7% from ridge tillage. Since total P forms were only determined from January to September, 1990, further research is required to substantiate these results. Tillage effects in this year were not statistically significant because of the high variability.

Phosphorus and sediment transport was also measured from a sod treatment in 1990. Results are not directly comparable to the corn treatments because sod received twice the amount of phosphorus as corn. However, several interesting inferences with the corn treatment can be made. Water runoff from the sod treatment was less than that from the corn treatment and ranged from 14 to 28% of the rainfall. Sediment transport was reduced to 129 kg/ha which was 30 to 37% of that from the conservation tillage treatments. Over 90% of the sediment loss occurred through subsurface discharge compared to 42 to 68% from corn culture. Dissolved orthophosphorus transport from the sod (6.5% of applied) was similar to that from ridge tillage

(6.4%). The percentage of total phosphorus loss (14±1%) from the sod treatment was also similar to that from ridge (15±7%) tillage. As noted for ridge tillage, much of the total phosphorus transported from sod was in the soluble form.

This work indicates that for a poorly drained, Brookston clay loam soil, conservation tillage effectively reduced soil erosion but not phosphorus transport. Transport of soluble forms of phosphorus were higher from both conservation tillage treatments than from the conventional tillage treatment indicating that these tillage practices may result in increased phosphorus bioavailability and reduced water quality. Further research will be needed to confirm the result that total phosphorus transport is also increased with conservation tillage. Thus, if the Great Lakes water quality objective with respect to phosphorus is to be met, alternative or modified conservation tillage systems will have to be developed. The introduction of crops which have a low fertility requirement may result in lower recommended rates of fertilizers and hence improved water quality. Research at Agriculture Canada, Harrow is continuing to study alternative crop and soil management practices that affect water quality (herbicides and nitrate) but resources are not available to include phosphorus. The approach is to develop a management system, whereby through water table control, a favorable environment for efficient use of nutrients applied for crop growth will occur.

PART B - HERBICIDES

EXECUTIVE SUMMARY

Conservation tillage with residue management has been proposed as the most effective means to reduce soil deterioration in southwestern Ontario. Residue management with conservation tillage has reduced soil erosion, increased organic matter content and reduced soil compaction. In some situations, impairment of water quality by pesticide contamination has been reduced by conservation tillage treatments. However, increased impairment of water quality has also been observed. A three year study was conducted on a poorly drained, low slope Brookston clay loam soil to investigate the effect of conventional tillage (fall plow, spring disk and mid season cultivation), zero tillage (direct planting in previous crop residue) and ridge tillage (planting in 15 to 20 cm high ridges, reformed in midseason) on surface and subsurface transport of atrazine and metolachlor applied preemergence to corn. Each runoff producing event was monitored to calculate the proportion of rainfall originating as runoff and water samples from the runoff events were collected for determination of herbicide concentration. Herbicide transport in the runoff was then computed for each event from the concentration profiles and runoff volumes. Residues of atrazine and its major dissipation product, des-ethyl atrazine, and metolachlor were determined in soil from the three tillage practices throughout the growing season and related to herbicide transport in the aqueous phase.

The proportion of rainfall originating as runoff was independent of tillage but dependent upon rainfall intensity, duration and antecedent soil moisture content. Less runoff (23% of rainfall) occurred in 1988 which was a dry year, compared to 28% in 1989, a normal year, and 36% in 1990, a wet year. Subsurface runoff exceeded surface runoff in all treatments. A greater proportion of the runoff occurred from the surface of the conservation tillage treatments compared to conventional tillage. The greater proportion of runoff from the surface of the conservation tillage treatments could impact on water quality since herbicide concentrations are higher in surface than subsurface runoff water.

Runoff producing events which occurred soon after herbicide application, transported the largest amount of herbicide. Where surface and subsurface runoff events occurred, herbicide concentration was highest in the surface runoff water and the mean concentrations were higher from the conservation tillage treatments than from conventional tillage. Herbicide concentrations of the runoff water were higher for metolachlor than for atrazine. However, because of the longer soil persistence of atrazine and inclusion of the primary metabolite, des-ethyl atrazine, in the amounts, less metolachlor was lost in the runoff water than atrazine. Tillage had no effect on transport quantities of atrazine and its metabolite or metolachlor. Average three year transport quantities for triazine (sum of atrazine and des-ethyl atrazine) were 58±1 g/ha from ridge, 36±3 g/ha from zero and 62±13 g/ha from conventional tillage representing 3 to 4% of total atrazine applied from 1988 to 1990. Up to 25% of the total triazine transported from the tillage treatments was the dealkylated (des-ethyl atrazine) product. Corresponding average transport quantities for metolachlor were 46±3 g/ha from ridge, 48±1 g/ha from zero and 53±6 g/ha from conventional tillage representing 2% of that applied. Atrazine and metolachlor on crop residue were readily leached into soil by rainfall received soon after application.

Minor changes in soil persistence of atrazine and metolachlor were related to tillage. Atrazine and its dissipation product persisted longer than metolachlor in two of three years and in some years both herbicides showed greater persistence on ridge tops than in the valley of ridge tillage. Soil persistence of the herbicides was longer in conventional than zero tillage.

In conclusion, tillage and crop residue did not influence herbicide transport in surface and subsurface runoff from a level plane, poorly drained soil. The proportion of rainfall appearing as runoff was similar among tillage practices, therefore the lack of a herbicide response to tillage was not unexpected. The quantity of herbicide transported from the three tillage treatments was less than 8% of that applied in the worst year while the three year cumulative loss amounted to <4% of that applied. Transport quantities of herbicide were more related to incidence of runoff producing events to herbicide application, rainfall intensity and duration, and antecedent soil moisture content. Tillage practices which alter the hydrologic response of watersheds will impact more on herbicide transport losses than tillage alone. Thus, tillage combined with other cultural practices such as band application of herbicide over the seed row, intercropping with a grass or legume forage, or adopting post emergence weed control strategies with low persistence herbicides should be investigated to determine their effect on impairment of runoff.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

APPENDIX
THE EFFECT OF CONSERVATION TILLAGE PRACTICES ON THE LOSSES OF PHOSPHORUS AND HERBICIDES IN SURFACE AND SUBSURFACE DRAINAGE WATERS

FINAL REPORT

May, 1992

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TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

FINAL REPORT OF THE TECHNOLOGY EVALUATION AND DEVELOPMENT (TED) SUB-PROGRAM OF THE SOIL AND WATER ENVIRONMENTAL ENHANCEMENT PROGRAM (SWEEP)

August, 1992

Prepared by:	ECOLOGICAL SERVICES FOR PLANNING LTD. Guelph, Ontario
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Disclaimer:	**The views contained herein do not necessarily reflect the views of the Government of Canada or the SWEEP Management Committee.**

EXECUTIVE SUMMARY

In August of 1985, the Governments of Canada and the province of Ontario announced the beginning of a coordinated federal/provincial program to deal with soil conservation and water quality as part of the Canadian response to an international agreement with the United States to reduce phosphorus loads to Lake Erie. A Five Year Implementation Plan was developed which set out the program objectives of a 200 tonne annual reduction in P loads due to agriculture. This target was to be met by encouraging and assisting 8,000 farmers cropping 400,000 hectares of land to adopt appropriate conservation cropping practices. Allocating the 200 tonne objective over 400,000 ha means that an average annual reduction of 0.5 kg of P per ha is required.

The Technology Evaluation and Development (TED) Subprogram of the Soil and Water Environmental Enhancement Program (SWEEP) ran from February of 1987 until September of 1992. This final report presents a summary of the subprogram.

The TED program was successful in responding to the research priorities identified during a detailed planning process. The planned research was implemented and completed on budget and on schedule making efficient use of a range of research capabilities throughout the province. The available research funds were equitably distributed between research institutions, such as the University of Guelph and the private sector. A number of productive joint ventures between research institutions, private sector contractors and active farmers were encouraged and supported. Regular review of the program progress with the Technical Advisory Panel resulted in modifications and research enhancements which improved the focus and overall achievement of the program objectives. Communication of research results and opportunity for input was provided to a wide range of interest through the use of Progress Summary Bulletins and research conferences.

The TED subprogram of SWEEP was conceived, developed and delivered as a cooperative venture between farmers, research scientists and administrative personnel. Any success which the TED subprogram achieved was due to the tremendous cooperation of individuals within these different groups.

Of the 53 research projects funded by TED, 21 (40%) were awarded in response to the formal Request for Proposal procedure, while 32 (60%) were awarded as a result of unsolicited proposals. Work conducted as a result of unsolicited proposals had to be justified by a demonstrated need for the knowledge which the work would provide.

The TED subprogram was given a mandate to focus on research conducted at the farm scale. Nearly 78% of all the research money spent during the TED subprogram was spent on projects which were conducted on viable commercial farms. In addition, an additional 5.5% of the research money was spent on studies which used a combination of farm and research station resources. Two hundred and thirty five farmers were directly contacted through the TED program. Of these 235 individuals, 148 were directly involved in some component of the TED research. One of the first projects awarded under TED was a survey of conservation practices being tested, revised and adopted by leading farmers in Ontario. This study was valuable to TED in refining the farmer position on research priorities and identifying a resource group of advisors and research cooperators.

In addition to supporting, strengthening and enlarging the network of farmer to farmer communication about conservation practices, the TED program assisted in the training and professional development of a number of technicians, researchers and research groups.

TED identified a need for tools which would assist farmers in reducing the risks associated with the transition from conventional to conservation farming. Means of providing these tools were explored to some extent at the TED Modelling Workshop held in November, 1988. An existing approach which showed the greatest promise was developed by ROBBERT ASSOCIATES, and derived from a five year program in Statistics Canada to develop a socio-economic resource framework. The promise shown by the first phase of the project conducted under TED clearly indicates a potential for meeting the established guidelines outlined above.

RESEARCH

Farm Managment Systems

A high priority research topic identified in the early planning stages of TED was the management of farm-field variability. The project arose out of the identified need to better understand the challenges involved in managing farm fields with complex topography, soils and drainage patterns. The main conclusions were that large amounts of soil and associated phosphorus are being moved within fields with complex topography in southwestern Ontario.; and the amount of soil and phosphorus moved within a field does not necessarily relate to the amount of soil and sediment delivered to streams. Therefore the crop productivity impacts of soil movement in complex fields can be significantly greater than the environmental and water quality impacts.

A study was undertaken to investigate an alternative farm management system developed by a group of innovative farmers known as the Ontario Biological Aeration Tillage Association (OBATA). Over the three field seasons of the research, many of the OBATA treatments appeared to have little or no quantifiable agronomic benefits. Soil fertility, structure and compaction, and microbial biomass did not appear to differ between the OBATA and standard treatments. Rainfall simulation indicated that the practices did result in reduced soil and phosphorus losses whem compared to conventional practices. While the TED studies did not show the OBATA system to be agronomically superior to the standard management system, it may be a viable alternative to conventional agriculture, offering comparable yields and net returns, while reducing soil erosion and phosphorus losses. Since pasture and manure management are readily included in the OBATA system, it may appeal more to farmers with livestock than those who grow strictly cash crops.

Cropping Strategies

The TED studies explored a range of management and species alternatives for cover crops and developed the establishment and elimination methods required to successfully incorporate their use into a farm system. The success of a succeeding crop often appeared dependent on using some degree of tillage in the spring prior to planting to provide an optimal seed bed environment in the presence of crop residues. Pushing residue aside was also often successful. Cover crops appear to have great potential to contribute to the reduction in soil erosion from cropland as evidenced by the biomass and residue covers which could be achieved over winter.

What is less clear from the research, is the link between main or cover crop residues and yield reduction responses. The effects of residues on soil temperature and soil moisture revealed that reduced temperature under residues may delay development but did not necessarily reduce soybean and corn yields. For example, the development of the nitrogen soil test would be a useful tool in the management of soil fertility with cover crops. Similarly, a screening test may be of help in choosing a corn hybrid that may be better able to emerge at cool temperatures.

Tillage Options

"Tillage Options" was identified as one of the research priorities for TED in the Background Paper, prepared by the Centre for Soil and Water Conservation, and by the participants of the initial planning workshop. Eleven tillage related research contracts were awarded during the TED program. Studies on subsoiling were included in the tillage options category as were development and testing of new planting or fertilizer application equipment for conservation tillage systems.

Several projects provided researchers and farmer cooperators with an opportunity to test promising new planting and tillage equipment under Ontario conditions. Minor modifications to existing technology were also tested such as the cutoff mold board plow which appears to be a viable first step for farmers towards conservation farming. Studies were conducted to assess the benefits of subsoiling on soil properties and subsequent crop yields . Overall, the TED studies did not come out in favour of subsoiling. It does not appear to be cost effective unless a severe compaction problem exists.

A contract resulted in the publication of a booklet by OMAF, entitled "Equipment Modifications and Practical Tips for Use." This publication contained photographs and descriptions of a wide range of modifications to moldboard plows, chisel plows, tandem disks, conservation seed drills, row crop planters and ridge-till systems.

Fertility Management

The confirmation that nutrient stratification exists in systems in which tillage does not mix or shallowly mixes fertilizer with the soil was expected. There is no indication that this would be of concern to farm management in terms of application rates and soil testing methods. The TED work indicated that increased phosphorus contribution from these fields is unlikely where conservation tillage acheives a concurrent reduction in sediment detachment.

Further, nitrogen losses from conventional, ridge tillage, and zero tillage corn in runoff and tile drainage were similar and there was no indication that conservation practices would lead to greater pollution of nitrogen in waters. A sod crop dramatically reduced nitrogen losses and nitrogen concentrations in runoff and tile waters relative to any of these corn systems, however, which would suggest that cover crops or intercrops may play a role in reducing nitrate leaching from soils.

The research which examined this possibility found that the cover crops of ryegrass, oilseed radish, and red clover, scavenged nitrogen initially but that soil nitrate levels were often as high or higher under the cover crops during the late fall and winter. The pattern of release of the nitrogen differed widely among the cover crops with some (oilseed radish) releasing too early to be largely available to a corn crop. while others immobilized nitrogen to the extent of depressing corn growth early in the season in the absence of supplemental nitrogen. There seems considerable opportunity to understand the contribution of cover crops in nutrient cycling.

There was some evidence from this same study that the various cover crops are leached of their nutrients to varying degrees by rainfall. The question of the importance of residues in contributing to soluble P levels was raised.

The manure management studies in TED provided useful agronomic information and tested some interesting and environmentally viable systems for manure applications. The design, timeframe and budget of the manure studies did not allow for full evaluation of the environmental implications of the management. In some cases the manure was not incorporated, such as the applications to established forages and to winter wheat in the spring. These systems have the advantage of providing high ground covers of 50 to 100% which could be expected to minimize runoff and soil erosion.

Other management systems, such as manure applications following winter wheat harvest and soybeans, provide opportunities for manure incorporation. When incorporation is accomplished by tillage which does not involve full soil inversion by moldboard plowing, the main crop residue may provide sufficient cover to reduce soil erosion. Some tillage was shown to be required to maximize corn yields the following year in these studies.

Pest Control

Research carried out since 1987 under TED provided substantial evidence to reject the notion that reduced tillage systems lead to greater weed problems and higher herbicide dosages. At the beginning of the TED program a very strong concern was expressed by the most experienced conservation farmers that weed management and the availability of appropriate products was, or could become a serious problem. By the end of the TED study it seems safe to conclude that their concern is significantly reduced. A number of new mixes and rates of application using currently registered materials and useages which have proven to be extremely effective in controlling weeds at reasonable cost. An innovative farmer was able to demonstrate a 60% reduction in herbicide use through the integrated use of a herbicide banding and interrow cultivation. This reduction offers significant environmental and economic benefits, while at the same time appearing to have no adverse effect on weed pressures. The system was developed to the point where the inter-row cultivation was performed at the same time as nitrogen fertilization which meant no additional passes across the field. In effect, the secondary cultivation allowed the farmer to save 60% on his herbicide bill without substantially increasing the costs of his field operations.

No significant problems with either slugs or armyworms were reported, despite the fact that in many of the research plots, residue cover was in excess of 75%. However, the lack of slug problems may be attributed to the drier than normal conditions which generally prevailed during the three field seasons. No evidence that fusarium infections can be linked to the adoption of soil conservation practices was found.

Water Management

Attempts under TED to monitor the water quality impacts of water control structures were unsuccessful due to weather problems. Some empirical data are required to calibrate available models. Once these data are available modelling should prove to be a more reliable and cost effective method of monitoring these structures.

Some tillage and farm management practices, such as cultivation, mulch tillage, residue management and cover crops, have the potential to increase the rates of infiltration and percolation into cropped land. A portable device, the Guelph Pressure Infiltrometer (GPI), was developed and used to compare the infiltration rates from soils under conventional and conservation tillage systems. The GPI provided rapid measurements of a number of soil hydraulic properties and is a promising research tool for further work.

Rainfall simulations were conducted in a separate contract on a large number of TED research sites. Although differences in surface hydraulic properties were not specifically examined, the response of different treatments to the simulated rainfall did show relative differences in surface infiltration rates. The results from the simulations were highly variable, but generally in agreement with those from the GPI study.

At a monitored upland site, surface and tile flow from a fall moldboard plow tillage system with a no-till system were monitored and compared. Very little surface runoff occurred during the first 12 months of the monitoring period. It was concluded that the sandy loam soils at the site were not susceptible to surface runoff and erosion under either the no-till or fall plow systems. When rainfall simulations were conducted on a part of the field that had clay loam soils, both runoff volumes and soluble orthophosphate losses were greater from the no-till soils.

The results from a monitored lowland site indicate that conservation tillage is not sufficient to reduce phosphorus losses from cropland located on flat clay soils. Other measures may be necessary, such as optimizing phosphorus fertilizer use, or controlling the flow and re-using the tile drainage water (subsurface irrigation creating wetlands, etc.), to keep the nutrients in the fields. The technology and options for accomplishing this was not investigated further.

Problem Understanding

Rated as a high priority was the examination of the nature, extent, and possible remedies to allelopathic and phytotoxic effects related to conservation farming and specific crop rotations. The specific compounds studied were volatile fatty acids (VFA's) which are by products of biological fermentation, and phenolic acids which are organic compounds initially leached from crop residues. Corn did not consistently exhibit a yield reduction response to the presence of crop residues on the soil surface and hence the observation of farmers related to phytotoxicity could not be reproduced in research trials in the field.

Studies were conducted to determine the extent of soil compaction on lowland clay soils in southern Ontario. Results indicated that around 50 to 70% of clay to clay loam soils in Lambton, Middlesex, Kent, Essex, and Elgin Counties have some degree of subsoil compaction. Twenty five percent of these are considered to be severely compacted. Subsoiling of these lands found that it was generally not beneficial to crop yields, and may be of use only on severely compacted soils.

As a progression from studies carried out in TED and Tillage 2000 examining variability of fields and effects of landscape positions on soil loss, research focused on shoulder slope erosion and the extent to which tillage operations move soil up and down slopes. This research is continuing beyond the TED term.

The report concludes with a discussion of the TED process and the Results of the research. Recommendations for the planning and management of future research programs are made. In addition specific topics for future research are suggested in the area of soil and water quality, farm management systems, soil fertility and nutrient management, crop residue management and tillage practices.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

FIELD EMERGENCE PREDICTORS FOR GRAIN CORN UNDER NO-TILL MANAGEMENT

FINAL REPORT

May, 1992

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Disclaimer:	The views contained herein do not necessarily reflect the views of the Government of Canada or the SWEEP Management Committee.

EXECUTIVE SUMMARY

A simplified screening test for field emergence of grain corn under no-till management.

H.J. Hope and Riad Maamari
September 1991

Rationale

It has been shown that when no-till (NT) management is practised with grain corn, plant residues on the soil surface can accumulate, shading as much as seventy percent of the soil from the warming effect of the sun. Springtime soil temperatures are 4-8°C cooler than under conventional till (CT) causing reduced seedling emergence and economic losses to farmers.

Objectives

A rapid, efficient laboratory measurement of corn cold tolerance during germination and early growth is needed to identify hybrids which germinate and grow best under cool NT conditions.

Methods

Two series of low temperature experiments (I and II) were carried out to do a detailed study (I) (see Part I) of germination on a small number of hybrids and a less detailed study (II) (see Part II) on as many hybrids as time permitted using the germination parameters identified in Series I as being the most efficient predictors of NT emergence under cool conditions.

In Series I experiments, seven hybrids each from DeKalb and Pioneer plus an internal standard, Pride 5, were studied. Germination was measured under optimal conditions at 25°C. Root and shoot germination and also 1 cm shoot production were studied in detail over a period of up to 45 days at 11°C. Growth of seedlings at 12°C during 4 weeks in a growth chamber was also investigated.

Series II work focused on a survey of 126 hybrids chosen from the Ontario Hybrid Corn Performance Trials. Germination under near optimal conditions was verified at 25°C. Readings on days 5 and 6 of germination at 11°C were done for root germination and on days 20 and 22 for 1 cm coleoptile production.

In addition to Series I and II, a brief report is included on a field emergence experiment performed by a farm group in 1988. It was possible to relate field emergence data on five DeKalb and five Pioneer hybrids to laboratory data on time to produce a 1 cm coleoptile at 11°C.

Results

Germination at 25°C was uniformly high, in most cases exceeding 90% in both Series I and II experiments. Of the 126 hybrids studied in Series II, only 4 were rejected for further study because of germination below 80%. The viability of hybrid seed from commercial sources was found to be generally very good.

In Series I, growth at 12°C over 4 weeks in a controlled environment chamber showed considerable contrast between hybrids with no potential to grow at this temperature and those which grew steadily. Interestingly, the check (internal standard), Pride 5, had the best genetic potential to grow under these cool conditions. Leaf number, chlorophyll content, anthocyanin content, plant vigour and root vigour were also studied but found not to be as efficient predictors of cold tolerance over the four weeks of study as root and 1 cm coleoptile production.

A detailed study of germination at 11°C over 45 days completed Series I work. Data was analyzed using the SAS statistical package and correcting germination curves for deviations from 100% viability using PROC PROBIT. Time for 50% production of root, coleoptile and 1 cm coleoptile as calculated by the probit routine was taken as the most representative measure of each physiological response. The relationships among time-to-50% responses were investigated statistically. A highly significant correlation of 1 cm coleoptile production (r=0.814, p=0.0002) to coleoptile germination was found while those to other physiological responses were not significant. Published data (H.J. Hope et al, 1992. Can. J. Plant Sci 72: 83-91) on time to 50% 1 cm coleoptile for 30 short-season maritime hybrids demonstrated a significant correlation with field emergence. In addition, a significant correlation (p=0.05) was found between time-to-50% 1 cm coleoptile production and the difference between field emergence under NT and CT (1988 field experiment). Further field work is needed to extend this limited comparison of laboratory and field data on 10 hybrids to a larger more representative group.

In series II, laboratory germination at 11°C for 122 hybrids was studied. Data on percent root germination after 5 and 6 days and 1 cm coleoptile production after 20 and 22 days were compiled. The widest distribution of data was found for roots on day 5 and for 1 cm coleoptiles on day 22. Using these 2 growth parameters, several predictors of cold tolerance were investigated. A weighting of three times as much for 1 cm coleoptile germination as for root germination is predicted to be most efficient (see conclusion 5) pending field verification.

Conclusions

1) Time to production of a 1 cm coleoptile is the best of the predictors of cold tolerance under NT management practices considered in this study probably because it gives a measure of low temperature tolerance to both germination and early growth. Use of this predictor allows easy identification of the above average hybrids.

2) CHU ratings do not correlate with cold tolerance.

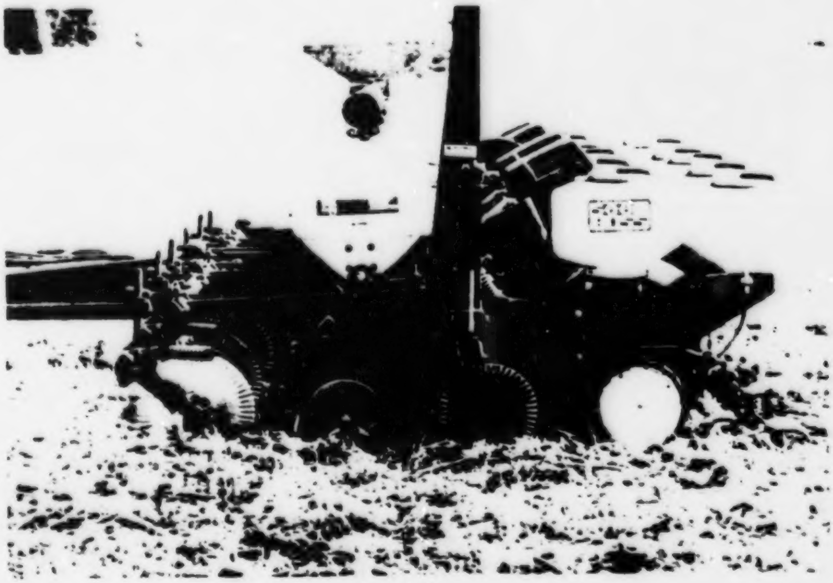
3) Seedling growth at 12^{o}C does not predict good cold tolerance during germination.

4) Rapid 1 cm coleoptile production correlates with minimal reduction in emergence of hybrids under NT as compared to hybrids under CT in the limited one year field trial from 1988.

5) Use of a cold tolerance rating is proposed as an efficient method of identifying corn hybrids that will emerge well under cold NT soil conditions. Field verification of this laboratory-derived rating calculation must also be done on a subset of the hybrids tested in the laboratory to assure the general applicability of the rating to hybrids grown in Ontario. Based on a rating scale from 1 to 100, hybrids would be grouped into three cold tolerance groups: 1 (very good), 2 (good) or 3 (average). A cold tolerance rating for a given hybrid, based on laboratory measurements would be calculated as follows:

$$[(\text{Day}_5\ \%\text{-germination}) + (3 \times \text{Day}_{22}\ \%\text{-germination})]/4$$

Conservation Tillage Handbook



Equipment Modifications and Practical Tips for Use

SOIL AND WATER ENVIRONMENTAL ENHANCEMENT PROGRAM

SWEEP

Canadä

Ontario

CONSERVATION TILLAGE HANDBOOK: EQUIPMENT MODIFICATIONS AND PRACTICAL TIPS FOR USE

FOREWORD

This handbook provides a pictorial overview of some examples of conservation equipment 'hardware' contributing to conservation farming activities in southwestern Ontario. By clearly identifying specific modifications and highlighting practical tips for use, this handbook orients the reader to the terminology and some of the system options available to those beginning or expanding conservation tillage practices.

Having access to appropriate tillage or planting equipment is only one of many management factors to consider when conservation farming. Other factors which must be considered include: weed, insect and disease control; fertilizer types and placement; crop types and rotations; use of livestock manures; and managerial interest and capability. Therefore, it is recommended that the reader contact their local office of the Ontario Ministry of Agriculture and Food, agribusiness personnel or others with experience in conservation farming before beginning the process of deciding which tillage equipment (or modification) will best meet their individual conservation needs.

DISCLAIMER

Conservation tillage equipment or practices highlighted in this handbook are based on user experience. Check with manufacturers for machine use and setup, as modifications may invalidate warranties.

Inclusion of any brand names does not imply endorsement of use by publishers of this handbook, nor does it suggest that other brand names are not effective.

The views contained herein do not necessarily reflect the views of the Government of Canada, the Government of Ontario or the SWEEP Management Committee.

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Don Lobb	Conservation Farmer, Clinton, Ontario

In addition, compilation of this handbook would not have been possible without the participation of conservation farmers who generously provided their time and practical knowledge of conservation farming systems. Their names appear on the inside back cover of this handbook.

This publication was prepared under contract to the Technology and Evaluation Development Subprogram of Agriculture Canada by the following staff of Ecologistics Limited, Waterloo, Ontario:

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October, 1989

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INTRODUCTION

The term 'Conservation Tillage' applies to many different types of tillage and planting equipment, as well as to the way in which they are used. One of the key goals of conservation tillage is to leave residues of previous crops on or near the surface of the soil. These residues cushion the erosive impact of raindrops on the soil surface, slow surface water flow, facilitate infiltration of precipitation into the soil, and conserve moisture. In Ontario, land is considered to be 'conservation' tilled or planted when at least 20 to 30% of the soil surface remains covered with crop residue after planting.

The equipment described in this handbook can assist the farm operator in achieving these residue targets. The handbook is organized by conservation tillage or planting system as described below:

1. *minimum or mulch tillage*—any system that includes some form of tillage in fall and/or spring in which crop residues are partially incorporated into the soil. On many soils, 20 to 30% residue cover is effective in controlling erosion.

   In this handbook, the modified moldboard plow, the chisel plow and other types of minimum till equipment are considered part of this tillage system.

2. *conservation seed drills*—a small slit is opened or a narrow strip of soil is worked by means of a non-powered ripple or fluted coulter running ahead of, or with the seeding units. Chemical weed control generally substitutes for cultivation.

3. *conservation row crop planters*—no seedbed preparation is required other than that provided by various optional non-powered attachments on the planter itself. The resulting tilled strip of soil in the row area is generally a maximum of 25 cm (10 in) wide and 15 cm (6 in) deep. Chemical weed control generally substitutes for cultivation.

4. *ridge tillage planting systems*—a ridge of soil is formed when cultivating for weed control in row crops. The succeeding crops are then planted directly onto the top of the ridge after the existing crop residue is removed, usually by non-powered attachments to the planter.

In order to put the equipment photographs into context, the discussion about each system includes the following points: equipment modifications, attachments and costs (when available); field conditions of use; and practical tips for use.

SECTION 2

Farm Level Economic Analysis (FLEA)

AN ECONOMIC EVALUATION
OF
TILLAGE 2000 DEMONSTRATION PLOT DATA
(1986-1988)

PREPARED BY:

DELOITTE HASKINS & SELLS

AS PART OF:

THE FARM LEVEL ECONOMIC ANALYSIS COMPONENT

OF THE

SOIL & WATER ENVIRONMENTAL

ENHANCEMENT PROGRAM (SWEEP)

FUNDED BY:

AGRICULTURE CANADA

AUGUST, 1989

EXECUTIVE SUMMARY

Deloitte Haskins & Sells undertook an evaluation of the costs and returns associated with a range of conventional and conservational tillage practices incorporated in the Tillage 2000 program.

The analysis incorporated results from 1986 to 1988 for corn, soybeans, winter wheat and barley.

Key findings are that:

1) Reduced (minimum) tillage practices produced generally higher yields and higher net returns per acre in corn, barley and winter wheat than conventional practices.

2) No till practices typically resulted in lower yields and higher direct input costs per acre for all crops. At the same time, significant machinery and labour savings resulted in higher net returns to no till than conventional or reduced tillage in winter wheat and equivalent net returns to conventional practices in corn.

3) No till and reduced tillage practices also had the same or a higher level of probability of achieving the same level of net returns in corn as conventional practices. That is, there was no greater level of financial risk in using reduced or no till practices relative to conventional practices.

4) High returns to labour for the no till and reduced tillage practices are evident and could well prompt farmers with high "opportunity costs" to labour to beneficially switch to these practices.

That is, farms with, for example:

a) labour shortage or difficulties at key work times;
b) higher returns to labour inputs in other enterprises eg. dairy; and
c) high returns from expanding the crop enterprise or the total farming enterprise.

AN ECONOMIC EVALUATION
OF
TILLAGE 2000 DEMONSTRATION PLOT DATA
(1986-1989)

Prepared by:

Deloitte & Touche

as part of:

THE FARM LEVEL
ECONOMIC ANALYSIS COMPONENT
OF THE
SOIL & WATER ENVIRONMENTAL
ENHANCEMENT PROGRAM (SWEEP)

Funded By:

Agriculture Canada

EXECUTIVE SUMMARY

Deloitte & Touche undertook an evaluation of the costs and returns associated with a range of conventional and conservational tillage practices incorporated in the Tillage 2000 program.

The analysis incorporated results from 1986 to 1989 for corn, soybeans, wheat and spring grains, on sandy, loamy, fine, silty and clay textured soils. Tillage 2000 has demonstrated a strong relation ship between soil texture and the ease of adopting a conservation tillage system. Any analysis of the data should consider the effect that soil texture has on the success of conservation tillage systems. A detailed analysis of Tillage 2000 is available in the Tillage 2000 1989 Progress Report.

Key findings are that:

1. No till and reduced tillage practices incorporated in the Tillage 2000 program are competitive with conventional tillage practices in corn and winter wheat.

2. No till and reduced tillage practices incorporated in the T-2000 trials were less competitive than conventional practices in soybeans and spring grains.

3. No till provides producers with realistic potential for significant labour savings and equipment cost savings when used in corn. Moreover, no till cropping operations would be more viable on farms with high opportunity costs to labour.

Specifically, farms with high opportunity costs to labour include the following examples:

a) labour shortage or difficulties at key work times;
b) higher returns to labour inputs in other enterprises, eg. dairy; and
c) high returns from expanding the crop enterprise or the total farming enterprise.

SECTION 3

Monitoring and Evaluation Committee (Monitor)

CROPPING, TILLAGE
AND
LAND MANAGEMENT
PRACTICES IN SOUTHWESTERN ONTARIO
1986

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March 1987

EXECUTIVE SUMMARY

This report represents the results of a survey conducted on 1,115 farms in southwestern Ontario in the fall of 1986. The purpose of the survey was to provide a detailed data base for the Soil and Water Environmental Enhancement Program (SWEEP). SWEEP is a five year program to reduce phosphorus loadings in the Lake Erie Basin from cropland run-off and to improve the productivity of agriculture. The survey gathered information on cropping, tillage, fertilization and land management practices in 13 counties and regional municipalities of the SWEEP study area. All of these factors impact on phosphorus delivery in the Lake Erie watershed. This data was complied to serve as a benchmark against which future progress in the implementation of soil and water conservation programs might be evaluated at the conclusion of the SWEEP Agreement.

The survey was conducted by means of a personal interview questionnaire, which was designed by the SWEEP Land Management and Cropping Practices Working Group, the membership of which is included as Appendix A. A draft questionnaire was reviewed by a cross-section of individuals involved in soil conservation work, and was pretested with a number of farmers. The final survey questionnaire involved 40 different questions and required 45 minutes to one hour to be completed. Most of the data was recorded on a field basis for each farm.

The sample drawn for the personal interviews was stratified on the basis of county or regional municipality, township, and erosion category. Based on 141 townships originally in the survey, 10 completed interviews were set as the target to maintain statistical reliability. The final stratification into soil loss erosion category (high/low) allowed the study area to be divided into areas where soil losses were above and below tolerable levels.

Survey results were compiled on a county and regional municipality basis. The many factors analyzed included general information relating to farms in the study area; erosion control practices; various tillage and planting operations; systematic, random and natural drainage; and manure, nitrogen and phosphorus applications. To assess the representativeness of the results, the information was compared to crop acreage as reported in Agricultural Statistics for Ontario (1985), Census of Agriculture (1981) data, and the 1984 study of Cropping, Tillage and Land Management Practices in Southwestern Ontario by Wall, Vaughan and Driver. Since a high degree of similarity exists between the results of the current survey and the information included in the above reference sources, it is possible to extrapolate findings to the county or regional municipality level.

Cash crop farming enterprises (43%) predominated in the SWEEP study area with five counties, Brant, Elgin, Kent, Essex and Lambton having more than half of their farms in this category. This was followed by dairy (185) and mixed farms (12%).

Swine, poultry, sheep, fruit and vegetables and tobacco together comprised over 18% of the study area. Results showed that the most common size of farm operation was 40-99 hectares (37% of responses) while the most predominate age category of operator was 45-54 (29%). Moreover, the predominant number of years the survey site had been farmed was within the 11-20 year category.

The principal crop grown in the study area was corn (36%), followed by beans (20%), forages (17%), fall cereals (12%), spring cereals (11%), fruits and vegetables (2%), and tobacco (slightly greater than 1%). Crop rotations were grouped into 6 categories based on combinations of row crops, cereals, forage, and pasture. Contrary to popular perception, only 1% of farm fields had no rotation at all. Rotations involving only row crops occurred 10% of the time. Forty percent of the fields surveyed contained a rotation of row crops, cereal and forage. In the 21% of the fields where a cropping change occurred within the last five years the main reasons for change were: economic (15%); reduction of erosion and better crop rotation (14%) each; and a change in crops, enterprise or land base (12%).

Survey results showed that only 3% of fields were strip cropped. Plowdown crop results showed only a 16% positive response rate. Three percent of the responses indicated the use of field borders. Land management control practices results showed that permanently vegetated buffer strips were the most common practice (23%), followed by erosion control structures (15%), streambank stabilization and tree windbreaks, each at (14%). Reforestation occurred least frequently, being reported only 8% of the time.

Farmers were asked to state the type of tillage equipment, timing of tillage, tillage depth and tillage direction employed on their fields. The moldboard plough (74%) and fall tillage (73%) are still common practices. It is encouraging to note the use of the modified moldboard plough, the disc/coulter and chisel plough. Their use, however, varied considerably from county to county.

Study results showed that most fields (61%) were primary tilled to a depth of 11-15 cm, while few (1%) were ploughed to depths greater than 26cm. However, it was surprising to note that a significant proportion of the fields were primary tilled at shallow depths (18%). Very little consideration for slope was given when ploughing. The direction most frequently ploughed (63%) was not related to slope. Contour ploughing occurred on only 5% of study area fields. The highest number of fields being contour ploughed were in Haldimand-Norfolk (12%) and Huron (11%).

Seedbed preparation (secondary tillage) methods were employed most often between March and May (85%). The most prevalent type of seedbed implements were the cultivator (49%) and disc and harrows (30%). Seedbed tillage was most often done twice. The most common reason for repeated tillage was that the seedbed was not fine enough. Approximately 20% of farmers have changed tillage practices in the last 5 years. Based on those who have changed, 30% gave the primary reason for change as a desire to reduce erosion. Additional reasons were changing crops, equipment or land base (19%) and to reduce cost (16%).

In the study area the most common type of planting equipment used was the row crop planter (45%) and the seed drill (46%). Modified row crop planters and seed drills, used to plant in heavy residue, were each used in only 1% of the fields of the study area.

Results showed that most farmers also tended to plant without consideration for the effects of slope (61%). A significant proportion (16%) plant up and down the major slope.

Results relating to systematic, random and natural tile drainage showed that systematic drainage frequently occurred in 5-10 hectare installations (33%). Randomly installed tile drainage most frequently occurred in small installations and least frequently in large installations. Natural drainage followed the same pattern. Forty-eight percent of responses indicated naturally drained areas being 1-4 hectares in size. Naturally drained areas of 21-40 hectares occurred only 6% of the time.

The use of manure, method of application, timing of application and the timeliness of its incorporation into the soil are all pertinent factors in understanding the potential effects upon water quality. In the SWEEP study area less than 40% of the responses indicated that manure was applied. Of those farms on which manure was spread, 83% of the fields were spread using a tractor and spreader. Responses indicated that 77% of the manure was applied during the spring, summer and fall. Only 9% of the respondents indicated they spread manure during the winter, while 14% indicated it was spread all year long. A cross tabulation of manure application with type of farm operation revealed that in the case of year round applications, dairy farmers accounted for (46%) followed by mixed (22%) and beef operations (15%). Where winter applications occurred, 34% were made by dairy operations, 23% by hog operations and 20% by mixed farm operations.

A review of the manure incorporation in the study area showed that approximately 30% of the time manure was spread onto forage crops. In only 14% of the responses was manure incorporated within the recommended 24 hour period. Almost one-third (32%) of the responses indicated that manure was not incorporated for more than three days.

Data on some 3,800 fields revealed that nitrogen fertilizer was applied on the basis of the farmer's experience (48%) and on the basis of a soil test recommendation within the previous years (27%). Applications of nitrogen were highest in the spring (88%)

with little variation by county with respect to timing of applications. The principal method of nitrogen application was broadcasting (49%).

Forty-eight percent of the responses about phosphorus, the main nutrient of interest in the improvement of Great Lakes water quality, revealed it was applied based on experience. Twenty-eight percent of the application were made on the basis of soil test within the previous year while 24% of the fields on the study area did not receive phosphorus applications. Applications of phosphorus were highest in the spring (83%). An average of 13% of the responses indicated fall applications, while 4% of the responses indicated both spring and fall. Two methods of phosphorus applications accounted for 95% of phosphorus applications: 48% of the responses indicated broadcasting was used, while 47% indicated application through the planter.

When farmers were asked questions concerning erosion control measures on their farms, fifteen percent indicated that erosion control measures were present. Most often the control measures had been privately funded.

The sources of information on soil erosion or conservation were farm publications (81%), radio and T.V. (65%), OMAF news (61%), books or journals (34%), and research institutes or universities (22%).

Earlier studies of erosion and sediment transport by the Lands Directorate, Environment Canada and the Ontario Institute of Pedology coupled with the compatible data from this survey can allow estimation of soil loss at the farm level and the whole study area by employing the Universal Soil Loss Equation (USLE). It can also be used to estimate the reduction in soil erosion as a result of changed cropping and management practices.

This report contains only the highlights of the extensive data collected through this survey. This data base will enable additional analyses and comparisons to be made and will be used to evaluate several aspects of the SWEEP program.

SURVEY OF
SOUTHWESTERN ONTARIO FARMERS
FOR THE EVALUATION OF SWEEP

JUNE 1988

Prepared for:

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File No. 228007

EXECUTIVE SUMMARY

The survey results indicate that decisions regarding a change in farm management planning are based on economics. Section 3.3.4 indicates that the farmer is concerned about how a change in conservation practices will make his operation more efficient and profitable. Question 33 asked whether or not farm managers considered soil and water quality conservation issues when planning their budget for a new year. Only 31 percent of respondents indicated that they did, while 54 percent stated that they made no budget allowances for conservation practices. However, these figures could be misleading because many of the respondents already were using some conservation practices and did not feel that they could afford to make further financial sacrifices. Some of the farmers who answered no indicated that such considerations were beyond their current financial means. These respondents did consider soil and water quality conservation issues when planning, but clearly felt that economics was the current priority. Therefore, we believe more farmers consider management practices in their budget then the responses to question 33 would indicate.

Another management planning issue concerns conservation practices used by the farmer on leased land. Thirty-three percent of the farmers surveyed indicate that part or all of their farm is rented. However, of these farmers who use rented land, only 51 percent indicate that their landlord is interested in soil and water conservation issues and 32 percent of these landlords have actually invested money in conservation practices. While 72 percent of the farmers surveyed take the same approach in considering conservation practices for rented land as they do for their own property, only 10 percent stated that they are obligated to use soil and water conservation practices in their lease agreement. For 54 percent of the renting farmers, the length of their lease is one year. Many farmers have indicated in their comments (see Appendix C) that conservation practices are not profitable on rented land because of the short length of the lease. Therefore, this would indicate that management planning for land that is continually leased on a short term basis may be less oriented to the use of conservation practices.

In summary, the analysis indicates that there is a wide prevalence of the conservation ethic in southwestern Ontario. Farmers are aware and concerned over the impacts of soil and water quality problems both on their own farms and the general environment. Soil erosion, run-off, and compaction are of particular concern among southwestern Ontario farmers. Furthermore, survey respondents are responsive to these soil and water quality concerns; the survey indicates not only that most farmers currently use conservation practices on their farms but also a willingness to adopt new conservation techniques. Barriers to implementing conservation practices on farms are based on economics, and reflect not only a lack of money and time to improve their land practices but also an uncertainty of how the change will affect the profitability of the farm.

A SURVEY OF
CROP RESIDUE IN
SOUTHWESTERN ONTARIO
1987

BY

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March, 1988

EXECUTIVE SUMMARY

This report represents the results of a study of crop residue test conducted by a combined windshield/on-site survey of over 10,000 fields in Southwestern Ontario in the spring of 1987. The purpose of the survey was to provide a detailed data base for the Soil and Water Environmental Enhancement Program (SWEEP). SWEEP is a 5-year program aimed at reducing phosphorus loadings from cropland run-off and to improve or maintain the productivity of agriculture in the Lake Erie Basin. The survey gathered baseline data for percent residue cover of the soil surface for various combinations of crops and tillage systems.

Conservation tillage practices increase residue cover and enhance erosion control. This data, along with that collected in the "Cropping, Tillage and Land Management Practices" report of March, 1987 will allow estimation of relative soil loss from fields. It will also serve as a benchmark against which the effect of implementing soil and water management practices can be evaluated at the conclusion of the SWEEP Agreement.

The survey was conducted by driving predetermined random routes twice through the counties of the SWEEP study area, with stops approximately every 0.8 km to record cropland information. At each site information was gathered on present crop, residue levels of the previous crop, and tillage type.

An attempt was made to include a representative sub-sample of interview survey sites visited in the "Cropping, Tillage and Land Management Practices" study (Coleman & Roberts, March 1987), in order to allow comparison of crop residue data with detailed cropping and tillage information.

An analysis of the data reveals that 16% of fields in Southwestern Ontario have 20% or more residue cover, while just 10% of the fields surveyed had 30% residue cover.

Residue levels were compiled on a county and regional municipality basis, by tillage type, previous crops and cropping sequence.

Study results showed that conventional tillage occurred most commonly (72.8%), while 18.6% of fields were not tilled, 8.0% were reduced tilled and 0.5% were ridge tilled. Over 95% of conventionally tilled fields occurred in the 0-15% residue category, while 3% of conventionally tilled fields occurred in the 75-100% category. For reduced tillage, most fields were in the 15-30% residue category at 40.6%, with a similar response (40.0%) in the 30-45% residue category.

The higher residue categories are dominated by fields in the not-tilled category. Most of this category was made up of forage and hay residue. These are densely growing crops which tend to provide a high degree of surface cover.

County results showing the distribution of crops planted indicate that corn (26.3%) was predominant. Hay or forage constituted 20.9%, while spring and fall grain made up 11.9% and 12.5% respectively.

To assess the representativeness of the results, the information was compared to the distribution of crops by county found in the report by Coleman and Roberts, 1987. A good deal of similarity was seen among percentage occurrence of the various crops between the two surveys.

Reliability of the crop residue estimate was judged by a cross-tabulation of actual measured residue cover in percent with estimated residue cover. For all residue cover categories, it was found that one can be over 96% confident that when a residue cover class was estimated, the value was in its proper class.

Residue levels of previous crops that were not identifiable (fallow), occurred 3.8% of the time in the Before Secondary Tillage (BST) phase, but their occurrence increased to 12% in the After Secondary Tillage (AST) phase of the study. Results showed that during the AST phase, higher proportions of fields occurred in the 0-15% residue cover category, while most decreases occurred in the 45-75% and 75-100% residue categories.

With the exception of small grains, the proportion of fields in the 0-15% residue category increased markedly during the AST phase, for most crops.

For example, the proportion of fields in corn having just 0-15% residue cover increased from 70.4% during the BST phase to 83.3% during the AST phase. By comparison, the number of corn fields having residue in the higher residue categories fell by approximately 13 percentage points.

The proportion of fields in beans having 0-15% residue increased from 61.4% during the BST phase to 95.6% during the AST phase. For beans, the higher residue categories lost a total of approximately 34 percentage points. With the exception of forages, corresponding losses in residue occurred for the remaining crops.

During the BST phase, 54% of forage fields occurred in the 0-15% residue category. These were fields which had been plowed down in preparation for planting another crop.

Hay which remained during the AST portion of the study was being kept an additional year. As a consequence, 83.5% of the entries in the 75-100% residue category are a result of forages being maintained from year to year.

Cropping sequences were one of the more interesting pieces of information available from the survey. For example, where the present crop was corn, 63.4% of those fields had previously been corn, 16.6% of present corn crops had previously been small grains while 11.1% of fields had previously been seeded to beans. Four percent of present corn fields had insufficient residue to determine what the previous crop had been.

An analysis of crop residue for a previous crop-present crop combination can show the probability of having a certain level of residue through many types of cropping sequences. As an illustration, the mean value of residue cover resulting from a corn - corn - grain - hay - hay rotation is provided. In the first year when corn follows a previous crop of hay, a 10% level of residue was found on average. In the second year when corn follows corn, one would expect to find 12% residue cover. In the third year of the rotation, when spring grain follows corn, an average residue cover of 9% would likely be found. When hay follows spring grain in the fourth year, a crop residue cover of 33% would be anticipated. In the final year of the rotation when hay follows hay an average residue cover of 73% would result. Over this rotation, the average value of crop residue was 27%.

Average residue cover levels for any other crop sequence can be derived with the data found in this report. Results showed that incorporating a forage/hay into a rotation increased crop residue cover substantially.

The survey was designed to collect information about crop residues before secondary tillage (after-wintering) and after secondary tillage (after-planting). The before secondary tillage information proved to be useful only in a limited fashion. The only crops in the before secondary tillage category during the spring are untilled crop stubble and primary tilled fields. Forage/hay and fall planted grains are crops which have already received secondary tillage. The main value of the before secondary tillage portion of the survey is to allow estimation of the over-winter protection afforded by stubble, forage or fall grain.

This report contains only the highlights of the extensive data collected through this survey. This data will enable additional analysis and comparisons to be made and will be used to evaluate the effects of conservation practices in the SWEEP program.

SECTION 4

Socio-Economic Evaluation (SEE)

TILLAGE 2000 AND ITS EFFECT ON AWARENESS OF CONSERVATION TILLAGE

by

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Prepared for

Soil and Water Environmental Enhancement Program

EXECUTIVE SUMMARY

INTRODUCTION

The major purpose of this study was to examine the factors that motivate farmers in southwestern Ontario to adopt conservation tillage practices. Specifically, this research focused on the adoption of conservation tillage practices in conjunction with Tillage 2000, an on-farm conservation tillage demonstration and research program.

Through analysis of the study results, it was hoped that knowledge of farmers' existing attitudes and perceptions could be used to develop more effective educational programs and incentives for higher levels of adoption.

MOTIVATING FACTORS FOR INVOLVEMENT IN TILLAGE 2000

The factors that motivated the demonstration farmers to participate in the Tillage 2000 program were varied. The majority wanted to experiment with and/or learn as much as possible about conservation tillage, and ranked this reason as "very important" (44 percent) or "moderately important" (19 percent). One-quarter of the demonstration farmers mentioned that they knew that someone was needed as a cooperator in their area, and felt they had a responsibility to participate. Another on-quarter were personally contacted, either by Tillage 2000 staff or conservation authority staff, and asked if they would participated in the program. In rank order, the remaining reasons given were: connections with the Soil and Crop Improvement Association (three respondents); previously practised some conservation tillage (three respondents); concerned about preserving agricultural land for the future (two respondents); and the adverse effects of conventional tillage (one respondent).

Overall, the cooperators exhibited the conventional characteristics of innovators. This was displayed through: their desire to experiment and gain new knowledge; their sense of responsibility about participating in the program; their connections with other organizations; and the fact that they were well known enough in their communities to be personally contacted by Tillage 2000 staff.

TILLAGE 2000'S IMMEDIATE IMPACT

Of the 107 randomly selected respondents, 25 percent 27 respondents) were aware of the Tillage 2000 program. Seventeen percent of the randomly selected respondents recognized the program's logo, and five percent had visited a demonstration farm. Only two percent of the randomly selected respondents had changed their tillage practices as a result of the Tillage 2000 program.

Neither location of or distance from the demonstration farms appeared to play a role in awareness of the program.

The program has not, so farm, had a great amount of impact on tillage practices in southwestern Ontario. However, the program was only in its second summer and had just published the results of its first year when the research for this study was conducted. The low rate of influence recorded was possibly due to the short time the program has been in existence.

Recommendations

In response to the findings and conclusions, several recommendations can be made:

1. It is recommended that research and extension agencies clarify what they mean by the term conservation tillage to avoid perpetuating the various perceptions and misperceptions among the farm population.

2. It is recommended that sources who supply information on conservation tillage emphasize that conservation tillage is a system. To obtain optimal results, conservation tillage, as a system, must be experimented with over time.

3. It is recommended that the effect of Tillage 2000 on awareness of conservation tillage be re-evaluated at the program's end, and the results compared to those of this study to facilitate a more holistic evaluation of the program's effectiveness.

4. It is recommended that Tillage 2000 staff increase their extension efforts to make farmers in Ontario more aware of pertinent local research.

On the basis of the researcher's overall impressions after finishing the research and analysis, on further recommendation can be made:

5. It is recommended that public and private extension agencies attempt to increase awareness of the availability of existing custom conservation tillage and/or conservation tillage equipment loan or rental, and recognize that innovators who have been practising conservation tillage for several years are a valuable information source. This measure might aid in increasing adoption through limited trail, rather than simply providing information on the benefits of conservation tillage.

AN ECONOMIC ASSESSMENT OF THE DISTRIBUTION OF BENEFITS ARISING FROM ADOPTION OF CONSERVATION TILLAGE PRACTICES IN CROP PRODUCTION IN SOUTHWESTERN ONTARIO*

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EXECUTIVE SUMMARY

The purpose of this study is to compare the on-farm and off-farm costs of soil erosion and assess the distribution of benefits arising from adoption of conservation tillage practices in selected watersheds in southwestern Ontario. The three watersheds studied are the Big Creek watershed in Essex County, the Newbiggin Creek watershed in Middlesex County, and the Stratford/Avon watershed in Perth County. The conventional tillage practice in all three watersheds is fall moldboard ploughing.

Simulation models are used to estimate changes in gross erosion, sediment delivery to streams, and farm net returns that accompany adoption of conservation tillage systems. A budgeting approach is used to estimate the off-farm costs of sedimentation from cropland and the off-farm benefits of adoption of conservation tillage practices. These benefits range from $9.93 to $71.70 per hectare and outweigh the on-farm cost of adoption in most cases.

In the past, the principal rationale for soil conservation policy in Ontario has been to preserve soil productivity. Recent emphasis on both soil and water quality with respect to soil erosion indicates that policy makers have begun to realize the magnitude of the off-farm impacts. The results of this study imply that this shift in emphasis should continue.

Sources of Motivation in the Adoption of Conservation Tillage

Prepared for the Soil and Water Environmental
Enhancement Program (SWEEP)

Agriculture Development Branch
Agriculture Canada

By: Stephen Connolly
and Prof. Stewart Hilts

EXECUTIVE SUMMARY

To date, research on agriculture and conservation has been largely devoted to attempts to identify farmers who are most likely to "adopt" a particular conservation practice or technology. Based on the Adoption-Diffusion model, this research has identified farmers in terms of socio-econmic factors such as age and education or farm characteristics such as farm size or farm type. This research has been criticized on several points, two of which are: it's inability to address the fact that conservation practices in agriculture are complex and variable, and it's inability to reflect the complexity of the individual's decision-making process.

This study presents a methodology which partly answers the above concerns by facilitating the "mapping" of ideas or sources of motivation. This process is applied to a survey in which farmers were asked to rate the importance of a variety of motivational and behaviourial factors.

The result of this process is the grouping of respondents into four distinct "clusters" which appear to be largely differentiated by the degree to which farm survival at a personal level is a motivating factor. Those farmers who appear to be most strongly motivated by survival tend to be the youngest, least educated and least experienced, farming the largest acreage. These farmers show average to good cropping, rotation and tillage practices though they use the least number of water management practices. Those farmers who appear to be least strongly motivated by survival have the highest average education, and farm the smallest acreage, they show average to good rotation, cropping and tillage practices and use the greatest number of water management practices.

SOCIAL STRUCTURE AND THE CHOICE OF CROPPING TECHNOLOGY: INFLUENCE OF PERSONAL NETWORKS ON THE DECISION TO ADOPT CONSERVATION TILLAGE

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THE SOIL AND WATER ENVIRONMENTAL ENHANCEMENT PROGRAM

SOCIO-ECONOMIC ANALYSIS PROJECT

EXECUTIVE SUMMARY

Objective

This report employs a multifaceted approach to examining the decision framework of farmers in relation to the decision to adopt or not to adopt conservation tillage. Responses from a representative cross-section of 259 farms surveyed in 1988 in the SWEEP project area are compared to those from a second, nonprobability sample of 55 known conservation tillage adopters for the purpose of examining the relative importance of various on-site, economic, sociodemographic, attitudinal and social network influences leading to the adoption of soil conservation practices.

A distinguishing aspect of this research is the focus of the examination of the farmer's social frame of reference constituted of family, friends and acquaintances to whom he may turn for information or guidance. Both the membership of this network and its structure are important. The membership of the network, ranging from spouse, through other family, friends, neighbours, and farm advisors constitute important sources of information on farming to which the operator may turn. In addition, the structure, or form, of this network facilitates or impedes the receipt of information concerning innovative farming practice.

Thus the research goals are: 1) to provide evidence of the influence of the structural characteristics of the farmer's communication network in enabling the diffusion of innovation of conservation tillage; 2) to assess information concerning what factors typically constitute the reference group of farmers with regard to decisions on tillage and other farm practices; 3) to assess the relative influence of social, economic, site and cognitive factors in leading to the adoption of new cropping technologies; 4) to compare known adopters with the general cash crop farming public of south-western Ontario on farm and operator characteristics; and 5) to estimate the relative rates of adoption of conservation tillage and other conservation practices among rowcrop farmers during the 1987 growing season.

SWEEP

Funding for this research was provided by a grant from the Socio-Economic Analysis subprogram of the Soil and Water Environmental Enhancement Program (SWEEP). SWEEP is a $30 million jointly funded federal-provincial program intended to reduce phosphorous loadings from non-point cropland soil erosion to Lake Erie by 200 tonnes annually by 1990. The Socio-Economic Analysis subprogram funds projects to evaluate the impact of SWEEP programs and to investigate the conditions under which farmers may choose to adopt conservation forms of farming.

Methodology

A two stage sampling plan was employed to select farms from the SWEEP project area for participation in a comprehensive survey of rowcrop farming practices. At the first stage a probability sample of cash crop farm operations was selected using conventional proportionate stratified, random sampling procedures. A random sample of 497 farms stratified by farm size and county location was drawn from the population of grain corn operations in the twelve counties of the SWEEP project area. Then, on the assumption that such a sample would provide too few farms on which conservation tillage was actually practised, a second, smaller sample was selected made up of 85 farmers previously identified as using conservation tillage.

The 582 sampled farms were surveyed by mail using a survey instrument comprising more than 200 questions for which information on the following topics was requested: 1) farm characteristics, 2) household composition, 3) soil and erodibility conditions , 4) farming practices, 5) attitudes, values and beliefs, and 6) personal network. With three follow-up mailings to encourage participation, 350 questionnaires from the 582 originally mailed were returned, for an overall response rate of 60.2 percent. Following exclusions for ineligible and uncodeable responses, the analysis group constituted 314 farms -- 259 farms from the probability sample and 55 from the conserver sample.

Findings

1. Farm Characteristics

A sampling objective was to select farms which were mainly row crop operations. Nearly 93 percent of the farms in the probability sample report producing corn, and 74.4 percent produce soybeans. There were no statistically significant differences between farms in the probability sample and the conserver group with respect to the type of products being farmed. However, the farms of the conserver sample are substantially larger than those in the probability sample, averaging 609 acres versus 339 in the probability sample.

The conserver sample farms were also somewhat more likely to be operated with another family member, not their spouse, or for the legal status of the farm to be a corporation, while self-owned, or ownership with spouse was more common in the probability sample. Most farmers, however, share ownership with at least one other. Few respondents to this survey, only 3.8 percent, reported renting or leasing their farm.

Once the difference in size of farms between conservers and the probability sample is taken into account, there is no difference between farms in the two samples in terms of farm assets. However, the conserver farms had significantly more debts, even in consideration of the large average sizes of these farms. The average debt to asset ratio across all farms in this survey is 34 percent, somewhat in excess of the thirty percent often seen as an acceptable debt to asset balance. Further, the conserver group had significantly lower returns on investment from their farming operations in 1987 in comparison to the farms of the probability sample. On balance the data on the financial aspects of the farm provide little support for a hypothesis that some farmers are conserving because they are financially better off.

2. Operator/Household Characteristics

The survey asked respondents about soil conditions on their farms and the existence of various types of erosion. Problems of water erosion and other soil problems are far more likely to be reported on the farms of the conserver group than the probability sample. Compared to farmers in the probability sample, operators in the conserver sample more often report their farms to have finer soil types, steeper and longer slopes, more soil erosion potential, more severe damage from erosion, and greater likelihood of both poor soil structure and soil compaction.

The operators in the conserver group were also more likely to admit their own farming practices to be contributing to soil erosion. In general, the conserver group had a greater tendency to recognize the potential for erosion, while ascribing personal responsibility for its existence. Only on-site inspection (not conducted) can ascertain whether the difference in the erosion levels of the conserver and the probability samples are actual or are simply perceived. However, it is likely that the farmers in the probability sample do not practice conservation as frequently as those in the conserver group because they are less able to recognize when it is needed.

4. Conservation Practices

The survey also examined the tillage and cropping practices used by operators in 1987 for evidence of conservation forms of farming. On this evidence there is some basis for optimism concerning the potential for soil conservation in Ontario. Although 86.5 percent of the farmers in the probability sample reported using the conventional moldboard plough in the fall, a surprising proportion, 47.6 percent, also reported using reduced tillage on some or all of their fields. Almost one-third of cropland for harvest for this sample, 31.3 percent, was affected by these methods. For the conserver sample, more than one-half, 51.9 percent, used conventional tillage on part of their farm in 1987, while 59.3 percent used reduced till, 22.2 percent used ridge till, 27.8 percent practised no till, and 31.5 percent used modified no till.

With the two samples combined, 44.6 percent of respondents reported using only conventional tillage in 1987. A further 36.3 percent used some combination of conservation tillage and conventional tillage, and 19.1 percent used only conservation tillage during 1987. Among farmers in the probability sample, 51.4 percent used only conventional tillage, while 35.7 percent combined conventional tillage with conservation tillage, and 12.9 percent used only conservation tillage.

Overall, nearly one-half of the farms in the probability sample, 48.6 percent, reported using some type of conservation tillage on their farms in 1987, and about one in eight farmers reported using only conservation tillage. In addition, 52.2 percent of these farmers reported leaving significant crop residue following planting in 1987 (versus 83.6 percent in the conserver group), with 37.8 percent of the cropland in harvest for that year being affected.

5. Attitudes

Environmental attitudes can be important pre-determinants to conservation behaviour. While in the soil conservation field most interest has been paid to factors involving the financial incentives for conservation, there is significant doubt that conservation will ever be seen by the majority of farmers to be financially attractive. Hence attempts to make conservation financially viable through government programs involving subsidies may be misdirected. While such programs may encourage farmers to adopt conservation, they also imply that the sole basis for deciding to practice conservation rests on its financial merits, while at the same time suggesting the government will accept responsibility for ensuring conservation is financially worthwhile. What this ignores is an approach to conservation which involves an individual's long-term willingness to prevent soil loss through conservation which is based on an ethical and moral commitment to the land, and which is practiced in spite of the extra effort and financial sacrifices which may be involved.

The survey found evidence that factors involving beliefs about soil loss, and attitudes about conservation and land stewardship were important to the farmer's decision to practice or not to practice conservation. There were statistically significant difference between the conserver and probability samples on a number of such beliefs, as well as the intention to practice conservation. This, on average, the conserver group was more likely to believe in the existence of soil loss problems in Ontario, while denying that farmland is mainly an economic commodity, or that the government, or other farmers, should be mainly responsible for solutions to soil loss problems. Farmers in the conserver group also saw themselves as believing that the overall benefits of conservation would, in the long run, outweigh its shortcomings, while stating they held a moral obligation to protect the land, and being committed to soil conservation through the intention to practice it.

The analysis also showed a relationship between these attitudinal and belief dimensions and the farming practices of operators. The majority of the attitudinal and belief factors were related to the intention of practicing conservation, in addition to predicting the likelihood of having used conservation tillage in 1987. Further, farmers who felt that conservation tillage was a bad idea from an economic perspective, were those who were least likely to try conservation tillage, while those who believe in its long-term benefits and need were those who were most likely to practice it. It is also the case that the geographical conditions of the farm with respect to soil and slope conditions, and the perceived evidence of soil loss on the farm, were positively related to the practice of conservation. This points to a need for the development of programs to help farmers recognize the existence of soil erosion on their own farms. The survey findings suggest that farmers are often committed to conservation, but are inhibited from practising it by being unable to recognize when it occurs on their own farms.

6. The Social Network

The notion of the social network in the context of adoption of conservation tillage adds a further dimension of understanding to the problem of how the decision to adopt conservation tillage is made. The idea that the social network may be important with respect to the farmer's decision to adopt or to not adopt conservation tillage is straightforward. Since before any change in farming practice can be expected the farmer must first receive information about the practice. It is through the social network that new information will be channelled.

Certain aspects of the network may facilitate more effective communication. These include the farmer's location with a sphere of acquaintanceship, as well as the size of the network and its density (proportion of reciprocal ties). Dense networks provide greater opportunities for communication transfer since there are more communication paths. On the other hand, dense networks may also be more "closed", to the extent that their tightly interlocking natures can prevent entry of innovative ideas. Finally, when dealing with innovative, or risky, new farming technology, there is likelihood that individuals with whom the farmer has a "weak" link will serve as a better source of information than with those with whom the link is "strong".

The latter idea centres on the understanding that each farmer's network may be differentiated according to both 1) degree of homophyly (similarity) between members of the network, and 2) level of attraction (strength of tie) between members. Thus homophyly and close attraction facilitate effective communication, while also acting to prevent new ideas from entering the system. Alternatively, heterogeneity within networks, and weak ties, give the system openness, enabling communications on farming innovations to flow freely.

Responses to the survey suggest the majority of farmers feel their friends and neighbours want them to practice conservation, and there are apparently few internal divisions within households to prevent this. In these respects both the conserver and probability samples are very similar. These factors, in addition, are related, weakly, to the farmer's intention to practice or not to practice conservation.

On the factors relating to the sources of information seen as important with respect to deciding on farming practices, there are no differences between the responses of the conserver and probability samples. The most important source of information is the farmer's own personal experience, followed by neighbours, the farm media, government and educational agricultural specialists, representatives of commercial firms, farm organizations, family members and one's spouse.

With respect to the personal network, the average size of the networks of the conserver sample is significantly larger than those of the probability sample. This is consistent with network theory generally which argue that larger networks provide more sources of information, and more channels along which it can be communicated, therefore facilitating the diffusion of innovation. Respondents in the conserver sample also had known members in the network for a shorter period of time, but there were no significant differences between the two samples concerning the frequency of interaction between network members, or their occupations. The majority, 64 percent, of network members are active farmers, followed by representatives of commercial or financial agencies, and government agricultural specialist. A relatively high percentage of the network members in both samples, over 40 percent, are people who either practice conservation or who belong to a farm organization which supports it.

The size of the network is also positively associated with the likelihood of having used conservation tillage in 1987, as well as with the intention to practice conservation and with the perception that soil erosion is a problem on the farm. Larger networks are also positively associated with younger and better educated farm operators, who have more debts, less returns on investment, and smaller farms. The density of the network is inversely related to membership in the conserver sample (nonsignificant), as well as with conservation tillage in 1987, and with intention to practice conservation, and the perception that soil erosion exists on the farm. Thus it seems that larger networks encourage conservation, while those which are dense inhibit it, either by being more closed and preventing the entry of information or by being comprised mainly of homophilous relations acting to resist ideas on novel farming techniques.

Closer inspection of the individual networks of farmers reveals that in terms of whom the farmer turns to most often and mentions as most important, when seeking information on farming matters, is likely to be another farmer. However, if the network contains a known conserver, or someone who is a member of an association which promotes conservation, then this person is likely to be referred to. On the other hand, when it comes to deciding something on the farm, the network, or reference group to whom the operator turns, is very likely to be comprised mainly of family, kin and other farmers, all individuals with whom the farmer, on grounds of obvious similarity, is strongly connected. Thus if the issue is whether to adopt a new and innovative farming practice, such as conservation tillage, networks comprised of member similarity and strong ties tend, on the whole, to counteract the chances of adoption.

Conclusions and Recommendations

On the basis of these findings, the following conclusions are warranted:

1) The decisions to adopt conservation tillage is multi-faceted. Across the range of dimensions investigated it is almost always the case that one or several factors stand out to distinguish members of the probability sample from the conserver group, or to identify conservers. Some of these-education,age, farm size -- are already widely known from the forty year research tradition on diffusion of innovation. Other factors, particularly those relating to attitudes, social normative beliefs, and network factors, are much less often recognized. Thus, farmers make up their minds to practice conservation, or not to practice it, based on many things, suggesting the need for the complexity of this decision frame work to be taken into account in the development of agricultural programs.

2) Conservation adoption is unpredictable. In spite of a number of significant associations across several dimensions, the correlations are, for the most part, not sizeable. Correlations in the range of .12 to .20 are common and, while statistically significant, can hardly be regarded as large. On these grounds it should be noted that identifying conservers on the basis of farms, or socio-demographics, or financial situation, or beliefs and attitudes, or social networks, or anything else, is never going to be easy.

3) There was little to suggest the financial conditions of farms are related to conservation. Large farms are more likely to practice conservation, true, but several financial indicators were unrelated to conservation adoption, while adopters also have significantly higher debts and lower returns on investment. However, the one factor which strongly predicts the intention not to adopt conservation tillage was the belief that such a practice would be uneconomical.

On grounds of these findings it may be concluded that programs to encourage conservation based on its questionable financial benefits are misguided. It often appears that in developing programs to promote soil conservation, planners have assumed the need to convince farmers of its financial benefits. However, an important factor predicting adoption of conservation practices in this survey was the farmer's moral commitment to conserve, and it is notable that such a factor is additionally inversely related to the belief that conservation is uneconomical. Soil conservation in Ontario may in the long run be better served by replacing an emphasis on economic returns with one which stresses land stewardship.

4) There may be more farmers in south-western Ontario practising conservation than was previously believed. Among the probability sample 12.9 percent of farmers reported using only conservation tillage, and a further 35.7 percent combined conventional tillage with conservation tillage. Further, 44.1 percent of the farms in this survey reported either now practising conservation tillage, or intending to practice it in the near future.

Still, it is also the case that the great majority of respondents, 86.5 percent, did use the moldboard plough in the fall on at least some portion of their farm in 1987. On balance it can be concluded there is some evidence of increased conservation occurring in south-western Ontario farming, and a willingness by farmers to do more.

5) A factor which appears consistently related to the likelihood of adoption of conservation forms of farming is the farmer's perception that soil loss is occurring on the farm. The belief that soil loss is occurring on one's own farm is a necessary condition for taking steps to prevent it. However, farmers cannot believe in soil loss until they experience it, and cannot experience it until the phenomenon is understood and recognised. If more farmers could be shown how to recognize soil erosion and to estimate its cumulative effects, they would believe in soil erosion and practice conservation.

6) An important goal of this research was to investigate the influence of the farmer's social network on the decision to adopt or to not adopt conservation tillage. In this regard the findings are suggestive, but not conclusive. The structural properties relating to the size and density of the network appear to be related to the dissemination of new information, as well as influencing the network's receptiveness toward innovative farming technology. The networks in the sample are characterized by highly homophilous and strong ties, properties which may impede entry of novel information. However, comparisons between the networks of adopters and nonadopters revealed little which distinguishes their behaviours. While the findings from this approach are not conclusive, it should be understood that these network variables introduce a new level of analytical complexity, and with continued investigation are still potentially rich in their ability to explain conservation adoption.

CONSERVATION PRACTICES IN SOUTHWESTERN ONTARIO AGRICULTURE: BARRIERS TO ADOPTION

A REPORT TO
AGRICULTURE CANADA
THE SOIL AND WATER ENVIRONMENTAL ENHANCEMENT PROGRAM
SOCIO-ECONOMIC ANALYSIS PROJECT

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EXECUTIVE SUMMARY

1) Purpose and Overview

Concern over the degradation of soil and water resources has prompted the development of numerous technological advancements in agriculture. These technologies, combined with the resurrection of some traditional farming methods, provide the means for using agricultural lands in ways that minimize environmental degradation. Despite these positive developments, technological advancements are of little value until they are applied. Consequently, there now exists considerable interest in identifying and evaluating the factors that influence technology transfer.

Soil conservation research in Ontario and other jurisdictions suggests that many farmers are aware of the existence of soil conservation technologies, and are favourably disposed toward land stewardship. Despite these facts, the adoption of conservation technologies and practices has not been widespread. It is now evident that positive attitudes and awareness are necessary, but not sufficient, to ensure adoption. The conclusion is that other forces are constraining many farmers from acting on their pro-conservation attitudes.

The purpose of this research is to identify barriers to conservation in agricultural land use, and to assess the prospects for their removal. The major objectives of the study are:

1. to identify the nature and extent of conservation practices by farmers in Southwestern Ontario,

2. to identify, characterize and evaluate the major barriers to the use of conservation practices, and

3. to consider factors which promote and/or obstruct adoption of soil conservation practices for policies and programs.

2) Strategy and Methods

The completion of this study involved a review of scholarly and professional literature, the collection of primary data pertaining to farms and farmers through the administration of a mail questionnaire and through telephone interviews, and the use of secondary data sources as appropriate. Primary data for the study were collected between August and November 1988.

The selection of the study area was guided by the geographical focus of the Soil and Water Environmental Enhancement Program, and the desire to include a range of biophysical conditions and farm business types. In view of these requirements, the counties of Kent and Oxford were selected for examination.

Prior to undertaking the analysis, it was necessary to devise a measurement technique for assessing conservation practices used among farms. A classification scheme was developed which reflected the intensity or level of conservation effort based on the number and type of practices used. The classification scheme was used to identify physical, personal and farm business factors related to higher levels of adoption. While considerable variation existed between adopter groups, over 90 percent of respondents claimed to use at least some conservation practice on the land they farmed.

3. Summary of Results

A range of variables relating to the human, physical, and economic characteristics of the farm operation were tested for their possible association with the use of conservation practices. Significant influences on adoption were: scale of farm operations, perceptions, perceptions of erosion and other soil problems, age of the farm operator, membership in farm organizations, concern over the seriousness of erosion as an agricultural issue, and tenure. Several possible barriers to conservation practices were inferred from the findings. They include lack of land, lack of investment capital, age (at either extreme), and may include failure to recognize soil problems, lack of knowledge regarding possible solutions, and lack of conservation concern.

The issue of reported or perceived barriers to adoption, and the prospects for their removal were addressed. While a broad range of barriers to adoption were identified, the most commonly cited were perceived inadequacy of the technologies, perceived lack of need for practices, financial constraints relating to investment capital and foregone income, and the difficulty of incorporating specific practices into existing management systems.

Nearly two-thirds of the respondents indicated that they were interested in adding some (or more) conservation practices to their management system. Several conditions or actions, needed to facilitate adoption, were identified. These included the need for proof of the effectiveness and efficiency of practices, higher profits in farming, financial and technical assistance to assist with implementation, and demonstrated need for changes to the current management system.

With respect to policy alternatives and implications, farmers responded most favourably to initiatives which feature assistance and education rather than legislation and regulation. While nearly 60 percent of respondents preferred some form of financial assistance, less than 25 percent listed economic factors as the key barrier to adoption. The study results indicate that increased extension, and applied research into the refinement of conservation technologies may offer more potential for increasing adoption than increased reliance on financial incentives.

AN ANNOTATED BIBLIOGRAPHY OF SOCIO-ECONOMIC SOIL AND WATER CONSERVATION RESEARCH

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EXECUTIVE SUMMARY

It has long been recognized that achieving soil and water conservation is dependent on individual decisions of farm operators. This is especially true in a voluntary compliance context where decisions are made as to whether conservation technologies will be adopted, adapted, or rejected. Research has established that both social and economic factors influence this decision process.

The following is an annotated bibliography of research that has examined the role of these social and economic factors in influencing the conservation adoption decision process. The literature was examine to assess the current body of knowledge in this regard, present this assessment in a organized fashion, and identify any research deficiencies to assist future researchers working in this area.

In view of the purpose of this project, annotations focus on social and economic factors. This socio-economic literature parallels and often overlaps a much larger body of research examining the physical processes associated with soil and water conservation. Understanding of both the physical and socio-economic dimensions is necessary for sound resource management. However, the emphasis in this report is on social and economic factors influencing adoption of soil and water conservation practices.

In consulting the annotated bibliography, users will notice a preponderance of research articles from the United States relative to Canada. This is not due to the issue being more important in one nation as opposed to the other, but to certain institutional arrangements found in the United States. Social scientists within land grant universities in the United States have had, and continue to have, access to long-term federal funds that have supported many of the projects annotated in this report. This situation, combined with the long history of public sector involvement through such agencies as the Soil Conservation Service, has stimulated considerable activity in all aspects of soil and water conservation.

The report begins by identifying a number of social (personal and community) and economic (farm firm and institutional) factors that may influence the use of conservation practices. Research articles were sought in nine electronic data bases, numerous personal contacts with experts working in this area, and manual literature searches. A total of 255 records (research reports) were annotated into the PROCITE software system. Seventy key descriptors or search terms were assigned to the records to enable users to locate references by subject matter.

Frequency counts were made of citations associated with the key descriptors or terms as a method discriminating major research questions and issues. These results were combined with judgements of staff to identify 12 major research questions. These questions served as a foundation for a workshop attended by researchers, extension personnel, and program managers. The objective of the workshop was to articulate and rank research needs. Nineteen research issues or questions were identified and ranked using nominal group techniques. Rating scores varied between 10 and 22 with 13 research topics receiving a score of 18 or higher. These results indicated that there are not one or two critical issues; rather there are a set of inter-related issues that need to be addressed in a coordinated or systems fashion. A summary of research needs (Chapter 4) arising from the annotations and workshop are discussed in the context of research design and approach, policy, economics, and technology transfer.

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CONSERVATION TILLAGE EQUIPMENT: AVAILABILITY, UTILIZATION AND NEEDS

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EXECUTIVE SUMMARY

Introduction

Background

Agriculture Canada commissioned InfoResults Limited to conduct a study of conservation tillage tillage equipment to determine the availability of various machines, their use by farmers and the farmers' needs which are presently not being met. One of the potential constraints to the adoption of conservation tillage practices is the lack of appropriate equipment. This project is a first effort to review the need for and availability of conservation tillage equipment.

Study Objectives

The objectives of the study were to: document the farmers' level of interest in conservation tillage and tillage equipment; determine the availability of different types of machinery: determine what modifications farmers have made; establish what manufacturers have done and are considering; and explore ways the government could assist innovators.

Research Procedure

A sample of 19 farmers, 10 extension personnel, 18 equipment dealers and distributors and 11 equipment manufacturers were interviewed using a standard questionnaire.

Research Findings

Introduction

The conservation tillage equipment was defined to include any equipment used to undertake primary tillage, seed bed preparation, or the planting of crops under limited or no till conditions. Conservation tillage refers to a cultivation system in which 20% or more of the crop residue has been left on top of the ground.

The reader should be careful in drawing definitive conclusions or generalizing too widely from a small sample of individuals. The scale of the study was relatively limited partly because of the exploratory nature of the study and partly due to resource constraints.

Conservation Tillage Equipment Experience

Almost all the manufacturers and dealers had experience in selling conservation equipment. Other major areas of experience with this type of equipment involved manufacture, design and import. More of the extension personnel than the other respondents had more experience in providing advisory assistance and advice to farmers. The types of CTE with which the respondents had the most experience tended to be seed bed preparation and planting equipment.

All dealers and extension personnel and four-fifths of the farmers were aware of modifications have being made to machines. About one-third of the manufactures were not aware of such modifications. More respondents mentioned that modifications were made to planters than to other types of machinery.

Machinery Needs

Fewer of the farmers than extension specialists or dealers believed that existing CTE allows farmers to meet their needs. Generally, all three groups agreed that farmers' seed bed preparation equipment needs are better met than those of planting or weed control equipment. One-third of the farmers say their own conservation equipment needs are not being met. The percentage of each group believing farmers have needs which are not being met were: manufacturers 46%; dealers 39%; extension 100%; and farmers 53%. The greatest unmet needs were: how to use existing equipment and equipment at moderate cost. The major reason given by farmers for other farmers needs not being met was their lack of knowledge.

New Equipment

The overwhelming majority to extension dealers and manufacturers expect new CTE will be developed in the next two or three years to meet farmers needs. Fewer, four-fifths of the farmers, expect new CTE will be developed. Reasons for anticipating new equipment were, an increase in demand, the belief new equipment is being developed and the innovativeness of farmers.

Ninety percent of the manufacturers and all the dealers believed that the market for conservation tillage and seeding equipment will increase. Just over one-quarter of both groups expect an increased demand for traditional tillage and seeding equipment.

More dealers than manufacturers believed modifications are under way to drills and planters. The dealers generally believed the modification equipment will be available in one year but all the manufacturers expected modifications would only be available in two years. The suggested areas of future emphasis when for future CTE were: seed placement/control; fertilizer placement; residue management; and herbicide application.

Conservation Farming

Almost three-quarters, 72%, of the respondents are quite or generally positive about conservation tillage. The least positive group were the extension specialists. They supported conservation tillage on the basis of reduced water and wind erosion and saving time and money.

Impediments to adoption of CTE, in the opinion of all the respondents were: too risky 33%; lack of awareness 28%; do not believe will work 17%; problems with clay soils 10%; and lack of equipment 2%. Other impediments to adoption volunteered by the respondents were: cost 41%; tradition 25%; and the lack of managerial skills 14%.

Awareness of SWEEP ranged from all the extension personnel, to 63% of farmers, 36% of manufacturers to 28% of dealers. The respondents had few suggestions as to ways by which SWEEP could encourage conservation tillage. Grants to farmers were only supported by six individuals. On-farm demonstrations were favoured by over half of the extension personnel and farmers.

Those aware of SWEEP supported more on-farm trials, using innovative farmers to demonstrate practices, networking, promotion, etc. The role of communication was emphasized.

Conservation Tillage Equipment

The respondents indicated there was less need to promote conservation tillage equipment than the concept of conservation tillage. Ideas suggested included grants, the rental of equipment, promotion and on-farm trials.

Role of Government

A minority approved of government giving grants to farmers or manufacturers. Actions suggested included a land stewardship program, research and better recommendations regarding specific pieces of equipment.

Conclusions

1. The adoption of conservation farming is not being seriously impeded by a lack of appropriate equipment. A lack of knowledge and traditional farming practices appear to be greater problems than appropriate equipment.

2. The cropping function central to conservation tillage is the planting activity. This is the area where most problems still exist despite the introduction of new planters and drills. Additional research on and adequate directions for operating various planters on different types of soils with varying levels of residue are required.

3. The machinery industry, encompassing manufacturers, importers, fabricators and dealers, appears to be interested in being made more aware of and involved in conservation farming.

4. The primary role of the governments of Ontario and Canada is one of communication to promote conservation tillage.

Recommendations

1. Agriculture Canada's communication with the farm machinery industry should be increased. Suggest SWEEP personnel establish contacts with the various industry organizations to keep them informed of program activities and research findings. Encourage greater participation by industry manufacturers, importers, and dealers in field trials, equipment evaluations, etc.

2. Increased on-farm demonstrations using various types of planting equipment.

3. Continue land stewardship type programs.

4. Maintain communication activities especially information of the "how to do it" type for farmers.